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THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Prof. Edwin J. Houston, A.M., Mr. Theo. D. Rand, Prof. Coleman Sellers, E. D., Prof. H. W. Spangler, Mr. S. Lloyd Wiegand, Committee on Publications, with the Assistance of Dr. Wm. H. Wahl, Secretary of the Institute.

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PLATE I.

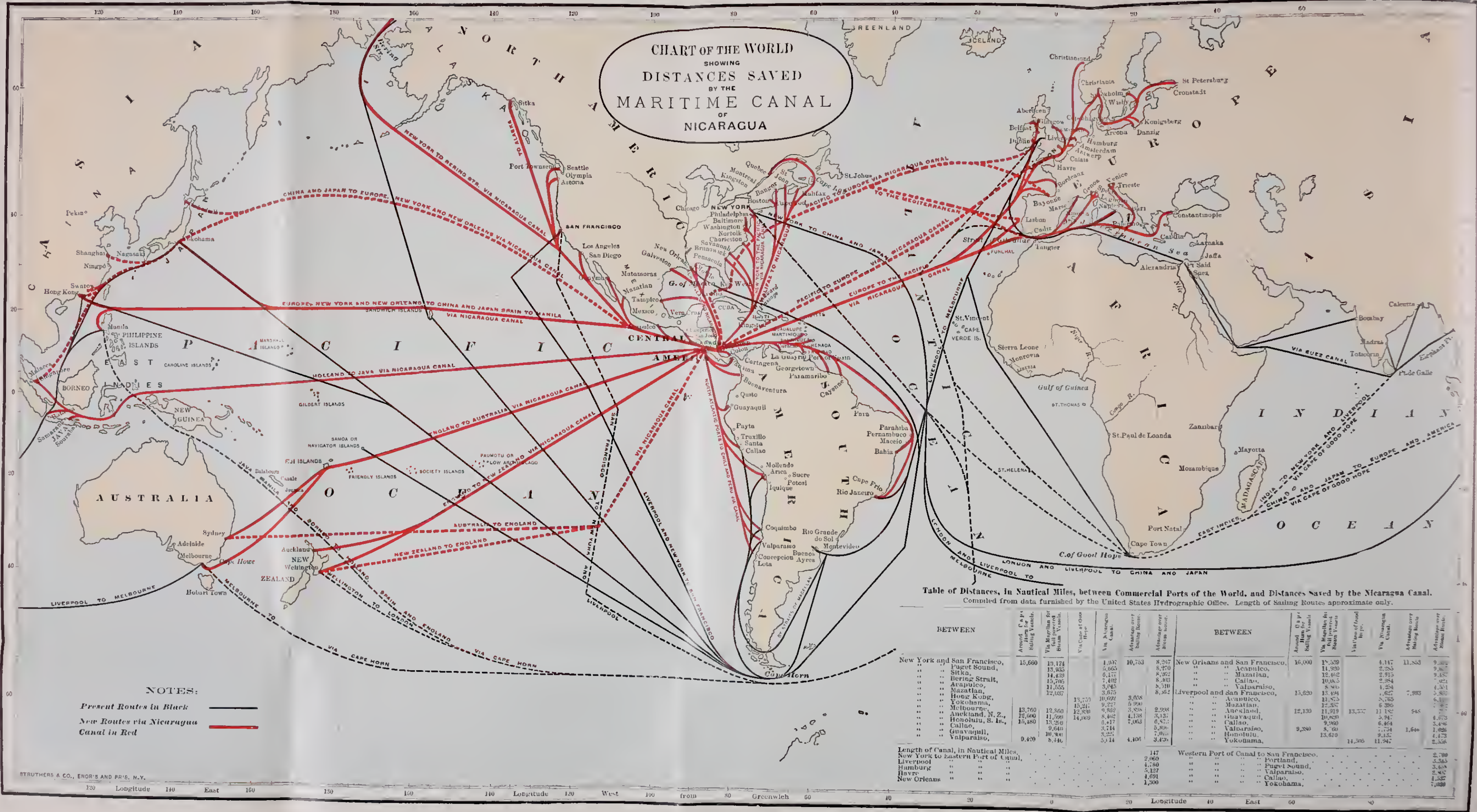


Table of Distances, in Nautical Miles, between Commercial Ports of the World, and Distances Saved by the Nicaragua Canal.

Compiled from data furnished by the United States Hydrographic Office. Length of Sailing Routes approximate only.

Between	Around Cape Horn for Sailing Vessels.	Via Magellan for full powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Route.	Advantage over Steam Route.
New York and San Francisco,	15,660	13,174		4,907	10,753	8,267
" " Puget Sound,		13,935		5,665		8,270
" " Sitka,		14,439		6,177		8,262
" " Bering Strait,		15,705		7,402		8,303
" " Acapulco,		11,555		3,045		8,510
" " Mazatlan,		12,037		3,675		8,362
" " Hong Kong,			13,750	10,692	3,058	
" " Yokohama,			15,217	9,227	5,990	
" " Melbourne,	13,760	12,860	12,830	9,862	3,898	2,998
" " Auckland, N. Z.,	12,600	11,599	14,069	8,462	4,138	3,137
" " Honolulu, S. Is.,	15,480	13,290		6,417	7,063	6,873
" " Callao,		9,640		3,744		5,896
" " Guayaquil,		10,900		3,225		[illegible]
" " Valparaiso,	9,420	8,446		5,014	4,406	3,432

Between	Around Cape Horn for Sailing Vessels.	Via Magellan for full powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Route.	Advantage over Steam Route.
New Orleans and San Francisco,	16,000	13,559		4,147	11,853	9,412
" " Acapulco,		11,920		2,255		[illegible]
" " Mazatlan,		12,402		2,915		9,487
" " Callao,		10,085		2,964		7,121
" " Valparaiso,		8,905		4,354		4,551
Liverpool and San Francisco,	15,620	13,494		7,627	7,993	5,867
" " Acapulco,		11,875		5,765		6,110
" " Mazatlan,		12,557		6,386		[illegible]
" " Auckland,	12,130	11,919	13,337	11,182	948	[illegible]
" " Guayaquil,		10,620		5,947		4,673
" " Callao,		9,960		6,464		3,496
" " Valparaiso,	9,380	8,760		7,734	1,646	1,026
" " Honolulu,		13,610		9,137		4,473
" " Yokohama,			14,505	11,947		2,558

Length of Canal, in Nautical Miles,	147
New York to Eastern Port of Canal,	2,060
Liverpool " " "	4,780
Hamburg " " "	5,127
Havre " " "	4,691
New Orleans " " "	1,300
Western Port of Canal to San Francisco,	2,700
" " " " Portland,	3,345
" " " " Puget Sound,	3,458
" " " " Valparaiso,	[illegible]
" " " " Callao,	1,535
" " " " Yokohama,	[illegible]

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIV. JULY, 1892. NO. 1

THE NICARAGUA CANAL.

BY GEO. W. DAVIS,
General Manager Nicaragua Canal Construction Company.

[*A lecture delivered before the Franklin Institute, January 8, 1892.*]

Mr. Davis was introduced by Dr. Wm. H. Wahl, Secretary of the Institute, and spoke as follows:

MEMBERS OF THE FRANKLIN INSTITUTE, LADIES AND GENTLEMEN:

With the subject chosen for this night's address, or the broader one of inter-oceanic communications in general, you are already familiar. I recall that my friend Admiral Ammen read a paper on this subject before this Institute some two years since, and I have interpreted your wish to be, to hear from me something pertinent to the present aspects of the problem of joining the two oceans, rather than to traverse

the ground already covered by those who have preceded me.

At the time Admiral Ammen read his paper on "Isthmian Canal Routes," December, 1889, the world had just learned of the collapse of the Panama bubble, although assurances from Paris of speedy resumption of work were afterwards heard. The untimely and lamented death of Captain Eads had occurred shortly before, and the ship railway project has since had no advocates sufficiently able to keep it before the public.

An eminent man, one of the most illustrious of the century, having joined the waters of the Mediterranean and the Red Sea by a sea-level canal at Suez, asserted that by no other than a similar means of transit at the Isthmus of Panama could the demands of commerce be satisfied. He declared that the work at the last-named locality would be "easier to begin, to finish and to maintain than the Canal of Suez;" and straightway hundreds of millions of money, even double the sum he demanded at first, were thrust upon him. After the expenditure of vast treasure and the sacrifice of thousands of human beings, but a small portion of the total cube to be extracted had been moved, and not only was the problem itself still unsolved, but it had become manifest at last that there had been no proper appreciation from the outset of the nature and value of its factors.

Another great man, having gained well deserved fame and prestige by the execution of engineering works of vast value to the nation and people, boldly proposed the novel idea of wheeled transportation over Tehuantepec of the largest deep-sea vessels. The brilliant reputation gained by this engineer in the opening of the Mississippi to deep-sea vessels, and in the execution of other very important works, secured to Captain Eads an attentive hearing, and for many years his scheme had many supporters. Most earnest efforts were made to secure Government aid for the project, and he endeavored to launch the enterprise as a private undertaking, but the world looked upon the scheme as a colossal experiment and his attempts failed utterly, the common

sense of mankind proving in this instance a safer guide than the confident assertions of a sanguine enthusiast.

The use of locks at Suez was unnecessary, and at Panama was at first declared inadmissible because of inevitable delays incident to the raising and lowering of vessels from one level to another. When the sea-level plan of construction at this locality was resolved upon, there was no precedent that could be cited in refutation of the argument advanced, but before the work at Panama had come to a standstill, the world had learned that the impediment to rapid transit of deep-sea vessels occasioned by locks was of very small moment, for at Sault Sté. Marie a lock almost as large as any required on the Isthmus had been passing vessels daily by the score up to 3,000 tons capacity. The English had already entered upon the construction of the Manchester Ship Canal, having spent several years in studies and surveys, and the most careful consideration of all existing methods of overcoming the difficulties. Among others, Captain Eads was called in as a consulting engineer, and the plan of a sea-level canal throughout from Liverpool to Manchester had many earnest and able advocates, but the lock system was finally adopted and the work is now almost completed. In another year the *Etruria* and *Teutonic* may discharge and load at the Salford Docks if it should be desired, and, locking down sixty feet, reach the sea some thirty-five miles away in less than six hours. Confronted with such demonstrations of the falsity of his reasoning, M. de Lesseps at last withdrew his objections to the lock, but collateral difficulties at Panama of almost insurmountable magnitude confronted him; besides the canal proper, he was obliged to provide two other artificial channels, of capacity adequate to conduct to the sea the entire drainage —tributary to the Chagres on either hand—of the flood waters that have been known to raise the level of that stream fifty feet in a few hours, producing veritable cataclysms that flood the whole valley all the way from the foothills to the sea. Confronted with these colossal besetments, being compelled to admit the false premise on which his plans were based, the people of France, becoming informed

as to the true conditions, refused further advances of funds, the inevitable collapse came, and now the courts of his country are endeavoring to fix the responsibility for the disaster.

It may be that some time in the future the inventive genius of mankind will devise methods for the economical transportation of loaded ships overland, but as yet these plans only exist in theory and must so remain until practical experiment has given a demonstration. Must the pressing demands of ocean commerce—supplied so readily at Suez, at Manchester, at Amsterdam and at Sault Ste. Marie—remain unfulfilled at the American Isthmus until the theories become realities, or shall the barrier be pierced and the seas united by means known to be entirely adequate to all requirements of safety, economy and efficiency—means that have been in constant use from the day when, more than 400 years ago, da Vinci built in Lombardy the first lock of which we have record?

The failure of others to achieve elsewhere the impossible should not restrain us from an effort to overcome the barrier that separates the two oceans, if the work is within the limits that always hedge commercial enterprises. The questions are therefore proper: What do we know of the magnitude of this undertaking, what the means required, what the time needed for its accomplishment and what its measure of usefulness?

I shall not detain you with an account of the efforts of the early navigators to discover "The Secret of the Strait," nor shall I allude to the surveying expeditions sent out by governments and individuals during the last half-century with the object of locating the spot where the difficulties are least forbidding. All this is a matter of history familiar to you and not pertinent to my subject, but it is of moment that some account shall be given of the steps taken to elucidate the problem at Nicaragua, for unless our knowledge be sufficient to enable us to value all the difficulties, we are deserving the same reproach that justly came home to M. de Lesseps—namely, that we entered upon the work of construction before we fully understood the magnitude of

the task. We cannot hope to interest capital, unless we can convince the ablest engineers and financiers of the practicability of our project, and we know that before the money will be forthcoming the ground must be examined, the plans studied, the measurements verified, and the estimates in all their parts justified, for in the launching of the Nicaragua project there can be no repetition of the spectacle that attended the presentation of the Panama scheme—the outpouring of a nation's wealth with no other security than the prestige of a great name.

The American solution of the problem of inter-oceanic communication has moved less rapidly but more surely on its way, as a full and intimate knowledge of its characteristics has been obtained, and it now commands public attention and confidence with constantly increasing assurance of ultimate success. The physical features of the lake and river route by Nicaragua have been carefully and minutely studied in all their relations, and have been made the subject of plans thoroughly elaborated in all details, and of estimates as thoroughly and carefully calculated. Every doubtful or difficult feature has been closely scrutinized and competent engineers pronounce the project unembarrassed by any difficulty save that of magnitude, which in this age is a hindrance only when it advances the cost of construction beyond the limit of remunerative returns.

I will sketch very briefly the means employed to supply the information that is felt to warrant the confident assurance I have just uttered.

EARLY SURVEYS.

For the first complete instrumental survey of the Nicaragua route, one that responds to the demands of engineering science, we are indebted to a citizen of Philadelphia, Mr. Oliver W. Childs, who in 1849–50 examined the whole route and pointed out the least depression that anywhere exists in the American Cordillera, from Alaska to Patagonia. The general accuracy of Mr. Childs' work has been fully confirmed by all subsequent examinations. The Government

survey of Lull-Menocal in 1872–73 was the next instrumental survey, and in the judgment of the Commission appointed by the President, at whose head was the Chief of Engineers of the Army, this was sufficient to demonstrate its superiority to all other routes from Tehuantepec to Darien.

In 1876–77, Mr. Menocal, while engaged upon civil work in Nicaragua added largely to existing knowledge regarding the topography near Greytown. In 1880, he also made a re-survey of the western division of the route—this by orders of the United States Government—and by the same authority in 1885 the same officer conducted very extensive examinations, looking to the divergence of the line from the San Juan River where it leaves the hills, and so to the avoidance of grave difficulties of drainage and maintenance, inevitable if the Childs' and Government location were followed all the way to the sea.

SURVEYS FOR LOCATION.

In 1887, the present concession for the utilization of this route was granted by the Government of Nicaragua to the agent of the present company, and in the autumn of the same year the work of final survey was begun under the direction of Mr. Menocal (who had been appointed Chief Engineer), and was uninterruptedly prosecuted, so that by the close of the year 1888 these definitive surveys for location and construction had been substantially completed, permitting the preparation of plans for building and the detailed estimates of cost.

The first corps of engineers despatched consisted of forty-five persons for technical work and 100 laborers, and was reinforced from time to time as occasion required. They were organized into six land surveying parties, one hydrographic party and two parties equipped for earth and rock borings. They re-located the entire canal line and acquired the most minute information concerning its every physical feature. In this connection I must call to your attention this fact which I think worthy of note, that while the length of artificial canal is less than thirty miles, the total length

of lines actually surveyed by transit and level in cross-sectioning, location of locks, dams, embankments, railroads, flowage lines, etc., is not less than 4,000 miles.

Upon the open, unprotected sea-beach in front of the Greytown lagoon—which was the former capacious harbor of San Juan del Norte—all supplies had to be landed, and this, in itself, was a very serious and expensive operation, for the vessels had to lie at anchor in the open roadstead two miles from land, where they were almost constantly exposed to the northeast "trades." These winds here usually have a velocity of ten to twenty miles an hour, and of course produce a violent surf, which had to be passed through in each trip between ship and shore. So difficult and tedious was the landing of cargoes there during the earlier operations before the opening of the harbor, that it was no uncommon occurrence for vessels laden with only ordinary packages of goods to depart without discharging their freight.

At first it was attempted to shelter the men in tents, but experience soon showed that canvas was neither an economical nor suitable protection. During all the surveying and other preliminary work inland, and even up to the present time, the workmen of all classes have lived in temporary huts, thatched with palm leaves, and many thousands of dollars have been expended for labor (there was no other outlay) on such structures.

The surveys were necessarily slow and expensive, for they were prosecuted in a tropical forest, where nothing could be seen at a distance of fifty feet, and where every step had to be preceded by the blow of a *machete* to clear away the tangled mass of vines and other vegetation that everywhere obstructed progress. The country along the line from San Juan to Ochoa was entirely without highways or other means of communication, except in a few localities, where navigation of the small streams was possible by canoes after clearing the water-courses from logs, stumps and other obstructions. From the small coast settlement of San Juan, where all supplies were landed and stored, all the way to Ochoa, a distance of thirty miles, the method of

transport of provisions and all other supplies, except in the restricted localities where canoes could be used, was similar to that employed by explorers in the heart of Equatorial Africa, viz: packs of suitable weight borne on the shoulders of men, up and down hills, so steep that support in climbing must be had from the brushwood or trees, much of the time with the rain pouring in torrents; through marshes and swamps where for long stretches the men had to flounder along in water and mud waist-deep, and this through a wilderness as wild and trackless as that about the head-waters of the Congo. No description can give an accurate idea of the tediousness, difficulty and weariness of this task.

The Government and other surveys by Childs and Menocal previous to 1886 had sufficed to demonstrate the feasibility of the general line of the San Juan River and Lake Nicaragua from Greytown to Brito for the Inter-oceanic Ship Canal route, but the present company, appreciating the importance of ameliorating, if possible, the difficulties to be encountered, could not properly omit the most careful investigations of very extended adjacent areas, in the hope of revealing an improved location in whole or in part. While the Government survey of 1872 served to demonstrate the entire practicability of the Nicaragua route, it will be interesting to know that of the line as now located between the Atlantic and the San Juan River, at San Carlos mouth, and also between the Pacific and Lake Nicaragua, a total distance of forty-nine miles, but about eight and one-half miles coincides with the Government route of 1872.

The Government survey of 1885 proved the superior advantage of a line diverging from the San Juan River near the mouth of the San Carlos, over the earlier location in the San Juan Valley, but the execution of the work on this route, remote from the river, involved the piercing of a ridge or spur of hills at a point which was some 500 feet high, unless a lower and practicable pass could be found, but the dense forest prevented an easy determination of this point. The passage across this ridge was but two or three miles long, yet in order to eliminate all doubt, and make certain

that no improvement was possible, it was necessary to examine the whole watershed and the approaches thereto for many miles on either bank, to meander every neighboring creek and rivulet to their origin on the Divide; in fact, to examine about every square rod of this highland, so as to permit the accurate plotting of all the information and the correct representation of all the topographic details on charts that could be studied at leisure.

Therefore, it is that the examinations have covered not only the one line first selected, but any and all routes that presented any indications of practicability. So, too, has it been necessary to explore every range of neighboring hills, and every small stream, in order to determine the limits and area of basins drained by streams flowing to or across the line. The Costa Rican bank of the San Juan River was critically examined from Rio San Carlos to the Colorado bifurcation, in the hope—which finally proved delusive—of finding a practicable site for erection of a dam twenty miles below Ochoa, that would permit the avoidance altogether of the ridge before mentioned, and the location of the line from the supposititious site of the dam at Point Sarapiqui through the San Juanillo valley to the port at San Juan del Norte; but the whole country on the Costa Rica bank of the river back for several miles was found low and flat, intersected with creeks and lagoons, forbidding the further consideration of the alluring suggestion of inundating the lower San Juan, and so saving many millions of expense in heavy rock cuttings; but it cost much time and money to ascertain that this idea, which had been urged by some intelligent men, was impracticable.

So soon as the first corps of engineers was landed, the surveying parties were organized and at once pushed out. Traversing the lowlands for a few miles back of Port San Juan, were some sluggish streams whose courses favored the idea of utilization for water-borne carriage of supplies. A steam snag boat was immediately set at work removing the obstructions, and barriers too heavy and massive for displacement otherwise were broken up with dynamite. The San Juanillo and Deseado were thus cleared and utilized

for a distance of upwards of thirty miles of their course, but the streams were so crooked that the actual land mileage accomplished was only about one-third the distance by water. The trails for the packers were cut out, foot bridges built across impeding streams and ravines, so that supplies could be transported with certainty, though slowly, to and beyond the Eastern Divide.

The San Juan River has long been used by a steamboat transportation company, and a large part of the produce of Nicaragua has for forty years been moved from the interior by this route. Steam transport *via* the river was, of course, availed of by the engineers when it served their needs, but much of the surveying work was remote from the river, and hence its unavailability, except in the region beyond the Divide toward Ochoa, where the canal and river were in closer proximity. As will be seen by reference to the map, the canal line beyond the dividing ridge intersected the valleys of the San Francisco, Chanchos and Danta. The channels of these streams were also cleared and made available for canoe traffic from the San Juan River. Numerous camps and depots of supplies were constructed and stocked wherever necessary, and fleets of light steel canoes were employed as means of communication and supply.

The idea was early entertained of utilizing the channel of the San Juan River for slack water canal navigation, and thus making it serve as a portion of the inter-oceanic ship transit route. Childs, in 1851, demonstrated its suitability for such use and the Government survey of 1872 confirmed the earlier observations and deductions, but in both these projects it was proposed to construct at each of the principal rapids, dams and locks of low lift, and thus to convert the stream into a series of pools or reaches. The general level of the canal at any point would, therefore, conform closely to the natural level of the river. Such a treatment of the problem would have precluded the shortening of the line and reduction of the expense gained by the adoption of the nearly direct "overland route" from this point to the sea. The excavation involved in passing from Rio San Carlos,

through the Eastern Divide at the natural level of the waters in the river, would have demanded double the work and expense that should suffice if the "lake level" were extended to the San Carlos, and maintained all the way through the eastern dividing ridge as is now proposed.

The confident belief was early expressed by the Chief Engineer that a series of low dams in the upper San Juan was not the best treatment, for he believed the "lake level" could be maintained to or below the junction of the San Carlos, and so the rapids in the river could be all submerged, but he realized that this treatment would demand, as a *sine qua non*, the erection and maintenance of a massive dam—across the main stream near the point where the canal diverged—high enough to raise the water level at its site to that proposed for the lake itself; in other words, the dam had to be high and strong enough to hold back the flow of this powerful river when its level should be raised fifty-six feet. It was soon ascertained that the natural conditions, at a place named Ochoa, were favorable as to the width of stream, character of bottom and solidity of abutments, for the erection of such a dam, but on further examination of Costa Rican territory it became necessary to make sure that the waters when so raised would not escape through the hills and lowlands bordering the river on this bank. Surveyors spent many weeks in the investigation, and secured exact information that fortunately proved the feasibility of the plan of embaying the waters of the river, and converting its valley into an extension of the lake, upwards of sixty miles in length.

The information collected by former expeditions in regard to the topography west of the lake, was so complete that to elucidate the problem of quantities and cost, less new surveying work was there required than along the eastern divisions. Nevertheless, the whole line was re-surveyed, and the additional information thus secured enabled the engineer to introduce important changes and improvements in location and plans of construction, that could not be embraced in the earlier designs.

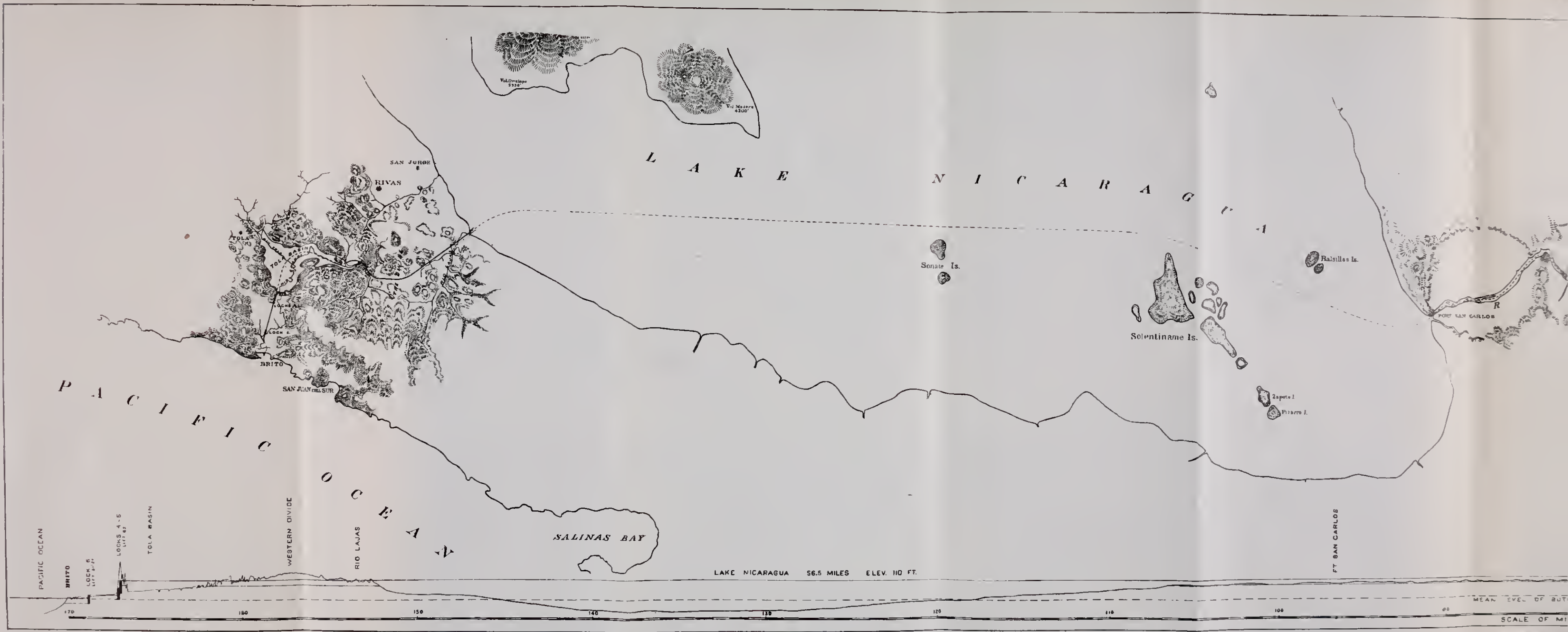
Every stream whose valley was to be utilized in whole or

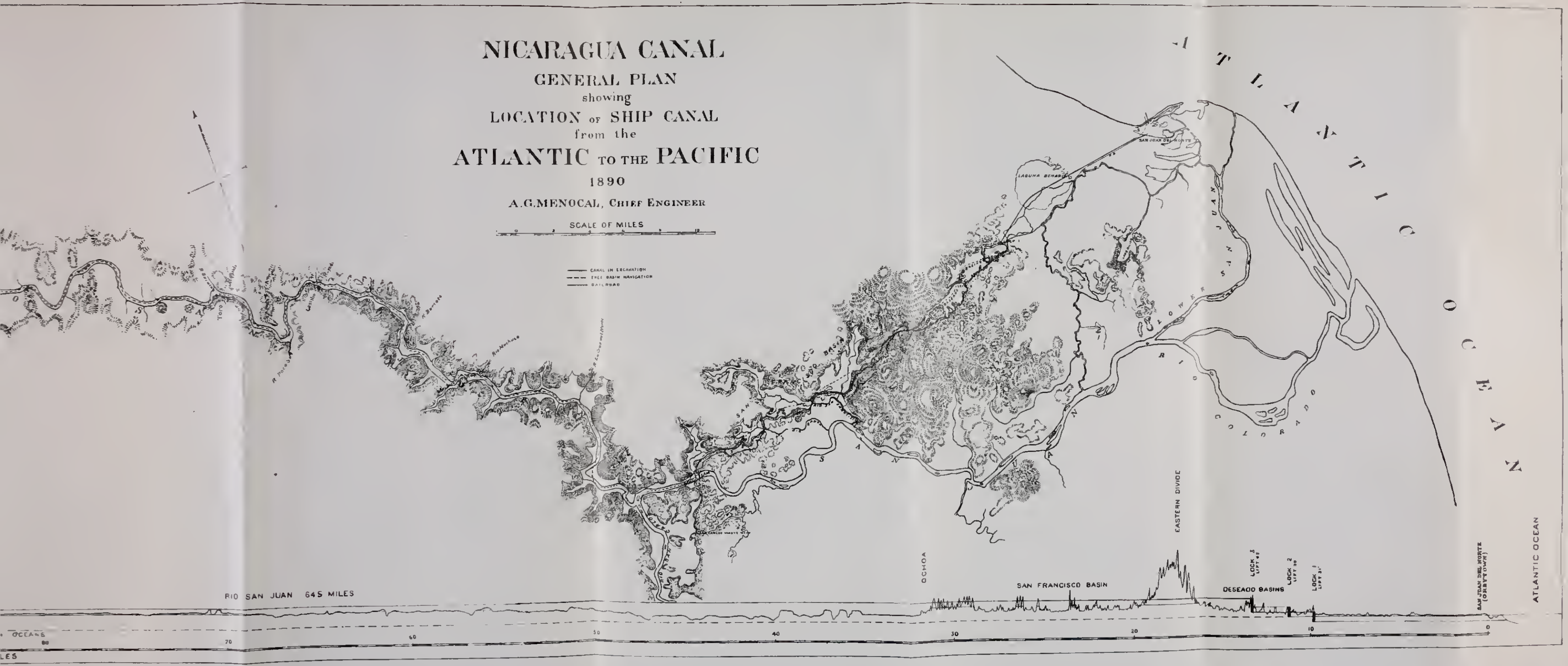
in part was thoroughly examined or traced in many cases to its source, its flow at high and low water was gauged and every question connected with water supply and disposal of surplus discharge was carefully studied.

But the work of the surveyor was not ended with the completion of these examinations of the ground. It was impossible to classify the material to be removed and assign a cost per unit, until exact knowledge was had of the nature of the concealed strata in all localities where excavations would be required. So the surveyors for "final location and construction" had to be equipped, not only for obtaining an accurate knowledge of the surface of the earth, but as well of the strata beneath the surface. For this purpose a boring and drilling equipment was provided, with which, at the site of all important works, such as dams, embankments and locks, as well as at the points where heavy cuttings will be required, subterranean examinations have been made in great numbers. Earth augers were used where there was no rock, and when this was encountered the annular diamond drill was used, and cores of the rock itself brought up and preserved for future reference and examination by engineers and contractors proposing to submit tenders for work. Owing to the transportation difficulties, steam drills were impracticable and the work was accomplished with hand-power.

THE ROUTE AND PROPOSED CANAL.

Probably some description of the canal itself, with the physical conditions under which it is to be built, would not be inappropriate at this time. Briefly, then, the distance from Greytown upon the Atlantic Coast, to Brito, upon the Pacific, is 170 miles, of which, however, a little less than twenty-seven miles is actual canal in excavation; the remainder of the distance is free navigation in the San Juan River, in Lake Nicaragua itself, and in basins formed by flooding the valleys of several smaller streams, such as the Deseado and San Francisco upon the eastern side and the Rio Grande and Tola on the western. But the key of the situation, and the one thing which renders it pos-


LAKE NICARAGUA
PACIFIC OCEAN
SALINAS BAY
SAN JORGE
RIVAS
TOLA
BRITO
SAN JUAN DEL SUR
Sonate Is.
Solentiname Is.
Balsillas Is.
PORT SAN CARLOS
PACIFIC OCEAN
BRITO
LOCK 6
LOCKS 4-5
TOLA BASIN
WESTERN DIVIDE
RIO LAJAS
LAKE NICARAGUA 56.5 MILES ELEV. 110 FT.
FT SAN CARLOS
170
160
150
140
130
120
110
100
90


NICARAGUA CANAL
GENERAL PLAN
showing
LOCATION of SHIP CANAL
from the
ATLANTIC TO THE PACIFIC
1890
A.G.MENOCAL, Chief Engineer
SCALE OF MILES
CANAL IN EXCAVATION
RAILROAD
ATLANTIC OCEAN
SAN JUAN DEL NORTE
LOWER SAN JUAN
RIO COLORADO
SAN JUAN
SAN FRANCISCO BASIN
EASTERN DIVIDE
OCHOA
DESEADO BASINS
LOCK 3
LOCK 2
LOCK 1
RIO SAN JUAN 64.5 MILES
OCEANS
70
60
50
40
30
20
10
0
ATLANTIC OCEAN

sible to build the canal and operate it successfully, is found in the lake itself, which is an inland sea, something like 100 miles long and 50 miles wide, and varying in depth to 240 feet. This lake, by receiving the waters which come down from the mountains into this great reservoir, prevents any sudden flood, and therefore, removes all danger to the canal from any excessive flow, which otherwise would occur. The outlet of the lake is the river San Juan, which, however, has two or three rapids, that can now only be passed by steamers at high water; during the low water period freight has to be trans-shipped around these rapids over a short tramway or carried over them in smaller boats. But the river itself is from thirty to 130 feet in depth. There is to-day plying upon the waters of Lake Nicaragua a steamer which was built at Wilmington, Del. The vessel steamed to Greytown, was taken up the river, and has been doing the entire trading business upon that Lake for eight years. That steamer, when it lies at what would be the beginning of the canal on the west side, is only twelve miles from the Pacific Ocean, and from the masthead, if there were a mast upon it, the Pacific Ocean could be readily seen. As I have before remarked, this lake with its outlet is the key to the situation which makes the canal possible, and in fact, it seems to open out a natural course for the inter-oceanic route.

All the surveys and plans of the United States Government, were based upon following the river San Juan throughout its whole course, and rendering it navigable by removing the rapids of which I have spoken and of building several dams and locks. Whilst this plan was undoubtedly possible, our company conceived the idea that we could abandon the lower San Juan, for the first twenty-five miles, where it is very crooked and spreads out in several channels over what is really a delta, such as is found at the mouth of the Nile and of the Danube. After careful and painstaking surveys, a route was found striking directly from Greytown across the lowlands, following the valleys between the hills to a point called Ochoa, on the San Juan River and which saved at least thirty miles in distance over

that involved by following the river in all of its windings. The discovery of this route will very greatly diminish the difficulties of building and maintaining the canal, and will add very greatly to its value when completed.

For the first ten miles from Greytown the line runs directly across low ground, raised but little above the sea. Here the canal will be made entirely by dredging, which is now in progress. The soil is composed entirely of sand and clay that is easy to work, and maintains its slopes after it has been worked. The end of this section brings us to the first lock, and then the next three and one-half miles include the locks with their dams and raise the canal to the level of Lake Nicaragua. From the Divide cut the canal traverses basins which are created by damming the streams which flow across the line and whose valleys are flooded. Through these basins there is little excavation to be done. Some gaps in the foot-hills have to be closed by dams and embankments. Just beyond the third lock we come to one of the most difficult parts of the undertaking—the rock cut. Difficult, I say, because of the length of time required to take out the rock, for there is no work simpler than rock excavation, or more carefully estimated as to its final cost and the time required. This cutting is between two and three miles in length, and averages about 140 feet in depth, but much of the material taken out is to be utilized for works on the canal itself. By means of the railroad which is now building, this rock will be carried down to Greytown to be used upon the breakwater or pier; the embankments in the foot-hills will be constructed in large part from the rock taken from this cut, and at the point where we strike the San Juan River, called Ochoa, there is a dam to be constructed across the river which will hold the waters at the level of the lake. This dam also will be constructed from the rock taken from excavation. If we had not this cut we would have to procure the material from other sources of supply.

As said before, the canal goes into the San Juan River at Ochoa, and from that point to the lake, a distance of sixty-four miles, there is free navigation, the river being

of a width for the largest steamers to pass and repass each other at full speed without danger. The rapids of which I have spoken are, of course, to be deeply submerged, and the canal enters Lake Nicaragua at San Carlos. Beyond this point some dredging is to be done in soft mud to reach the required depth, and after that it is clear sailing across Lake Nicaragua, a distance of fifty-six miles, to the point where the canal leaves the lake upon the western side.

The length of the canal on the west of the lake to Brito is, by the line followed, seventeen miles. The point where the canal crosses from the lake is the lowest land in the whole range of mountains reaching from the United States down to the southern point of South America. The pass is only forty-three feet above the surface of the lake. A cut of about five miles is here to be made, leading to what is known at the Tola basin, and the average of excavation is only twenty-one feet. The canal then traverses this large basin, covering many thousand acres and of an average depth of about fifty feet. At the farther end of the basin three locks bring the canal down to the level of the Pacific Ocean at Brito. There is now only a partial harbor at Brito, and a breakwater has to be constructed there as at Greytown upon the east side. Upon the northern side of the harbor there is a natural headland of rock, which projects into the ocean a considerable distance. We build a breakwater to the south of this natural headland, and then by some dredging we secure a safe and commodious harbor.

This is a brief description of the work which has to be done. There are no unsolved problems in it. Engineers who have examined it and the practical builders who have gone over it, one and all say that it is simply a plain work. It comes down to a certain number of yards of rock to be excavated, a certain amount of earth to be removed, locks to be built, and dams to be constructed and the creation of harbors; in short, there are no physical or engineering difficulties whatever in the way. If the canal had been proposed to be built of the ordinary dimensions it could have been done for a very moderate sum, but the plan of

our company calls for the construction of a canal which will pass the largest ship afloat. The minimum depth of water is to be twenty-eight feet. The size of the locks is to be 650 feet in length and 80 feet in width, and 30 feet in depth. There is no experiment about these locks or their capacity to pass the traffic.

As I have said, there is no experiment in the construction and operation of these locks. The United States Government built the first great lock of the world; that is, at the Sault Ste. Marie, connecting Lake Superior and Lake Huron. That lock is the prototype of those we propose to build, and of the same size with the exception that ours have a greater lift. The wonderful success of the canal at the Sault Ste. Marie has induced building similar locks in other parts of the world. As to their capacity to pass commerce, I need simply to call your attention to the fact that last year, in 234 days, the time the Sault Ste. Marie lock was open for navigation, it passed nearly 9,000,000 tons of shipping, or nearly fifty per cent. more than passed through the Suez Canal. The Government of Holland is building a similar lock of these dimensions on the Amsterdam Canal. The German Government is also building four great locks of the same dimensions or larger, upon a great sea canal across the Peninsula Holstein, which is to connect the Baltic with the North Sea, thus saving a distance of 700 miles over the route around Denmark, but the work is being constructed as a matter of national defence, for it connects the naval station at Keil, upon the Baltic, with the mouth of the Elbe, upon the North Sea. This canal is over sixty-three miles in length, and the amount of excavation to be done upon it is fully equal to the excavations incurred upon the Nicaragua Canal. The world has heard little of this great work, because it is being carried on entirely by the German Government, having therefore but one stockholder; there are some 8,000 men employed upon it. The canal will be completed and opened in three or four years from the present time.

CAPACITY OF THE CANAL.

The Suez Canal has been found of inadequate capacity to supply the increasing requirements of commerce, although

nearly 7,000,000 tons passed through it in 1890. To supply these requirements and permit greater speed, its width—now seventy-two feet on the bottom—is being increased.

At Nicaragua it has been felt to be necessary to provide at first for the most ample capacity. As regards dimensions of the canal prism, provision has been made as follows:

Length. Miles	*Width—Feet.* *Top.*	*Width—Feet.* *Bottom.*	*Depth—Feet.*	*Area of Cross-section Square Feet.*
9¾	288	120	28	5,712
2⅞	210	120	30	4,950
5⅜	184	80	30	3,673
8	80	80	30	2,400
21⅝	basins		30 and upwards	
64½	river		30 "	
56½	lake		30 "	
¾	locks		30 "	
169⅜				

A speed of five miles per hour is taken as a minimum in those sections of the canal having a cross-section equal to or greater than that at Suez. It is conceded too that in the eight miles having a sectional prism of 2,400 square feet, the speed may fall to two and one-half miles per hour. In the basins seven miles per hour, in the river eight miles and in the lake ten miles are certainly practicable, for it must not be forgotten that the 100 miles at Suez have been traversed in less than fifteen hours. As regards the time required for our six lockages, I would remark that it requires eight minutes to empty the great lock at Sault Ste. Marie, and eleven minutes to fill it. The complete lockage of a 3,000-ton steamer there takes only thirty minutes and it has been done in considerably less time. We allow forty-five minutes at Nicaragua for this operation. Basing our computations on these figures, we find it will require twenty-eight hours to pass a ship from ocean to ocean through the 170 miles of canal, basins, river, lake and locks.

The water supply is ample for a business exceeding by nine times the maximum that we expect for many years to come.

ESTIMATED COST.

The total cube of earth and rock to be extracted reaches the aggregate of slightly above 70,000,000 cubic yards.

Of this 34½ million yards of dredging are estimated at 20 cents; 5⅓ million of same material at 30 cents; 15½ million yards of earth excavation at 40 cents, and ¼ million at 50 cents; 6½ million of rock excavation at $1.25; 7 million yards of same at $1.50 and ½ million sub-aqueous rock at $5.

In embankments nearly 10,000,000 yards of material will be needed. The estimated cost of depositing this in place is taken at prices varying from twenty cents to $1.50 per yard.

Of masonry, over 634,000 cubic yards will be required. This will be principally of concrete; all the ingredients except cement are at hand. This is assumed to cost in place from $6 to $10 per cubic yard. It is also provided that the banks of the canal in many stretches shall be revetted with stone laid on the earth slopes and 264,000 yards are provided for at a cost of $2 per cubic yard for transportation and placing.

For land clearing $350,000 are allowed and forty-five miles of railroad at $60,000 per mile, and eighty miles of telegraph line at $500 per mile. For lock machinery, etc., nearly $2,000,000 are allowed. Appropriate amounts are also set aside for electric lighting, buoying of the whole canal line, light-houses at the termini and beacons. In fact, every expense that can enter into the construction has been anticipated and costs allowed.

The following is a recapitulation of Mr. Menocal's estimates, corrected to January 31, 1890:

RECAPITULATION.

Eastern Division,	$23,686,048 30
San Francisco Division,	5,163,318 10
Lake and River Division,	5,692,556 70
Western Division,	17,525,417 45
	$52,067,340 55
Surveys, hospitals, shops, management and contingencies, 25 per cent.,	13,016,835 45
Grand total,	$65,084,176 00

Early in the year 1889 the engineering estimates, plans and all official data that had been previously collected, and that had a bearing upon the technical question were submitted to a board of distinguished civil engineers for their revision and opinion.

The gentlemen referred to were:

Mr. John Bogart, State Engineer, State of New York.

Mr. E. T. D. Myers, Railroad Engineer, Richmond, Va.

Mr. A. M. Wellington, editor *Engineering News*, of New York.

Mr. H. A. Hitchcock, Prof. Engineering, Dartmouth College.

Mr. Charles T. Harvey, former Chief Engineer, St. Mary's Falls Locks.

All are well-known and distinguished in their profession. The report of these gentlemen is an exhaustive document, going at length into all the details. They give their reasons in full for increasing some of the estimates submitted and make a much larger contingent allowance than did Mr. Menocal. They estimate the total cost of the work at $87,799,570.

Other engineers of high repute have examined all our data, which are very voluminous, and contracting engineers have also submitted proposals for different sections or divisions of the work after a careful and minute inspection of the whole line. A contracting firm of entire competence and responsibility stands ready to contract for all the work required west of the lake, for a sum within our engineers' estimate.

The work is projected as a private enterprise, and we are well aware that other expenses, which the engineers cannot take into account, must be provided for; such as commissions for raising the required capital, interest on the several amounts paid in during construction and accruing before the line can earn dividends. We base our calculations on a total expenditure of all kinds—to be incurred before the route is opened for traffic—of $100,000,000, which is substantially what the Suez Canal cost.

The time required for the execution of this great work,

which is, perhaps, the most important undertaking yet remaining for our race to accomplish, is estimated at six years by conservative engineers who have studied carefully every physical question connected with it.

[*To be continued.*]

THE DEVELOPMENT OF AMERICAN ARMOR-PLATE.

BY F. LYNWOOD GARRISON.

[*Concluded from vol. cxxxiii, p. 453.*]

THIRD DAY, JANUARY 13, 1892.

Both plates tested on this day were made by Carnegie, Phipps & Co. One of them was a low-carbon steel plate and the other was high-carbon nickel-steel, both treated by the Harvey process. The plates corresponded in their chemical composition with two plates from the Bethlehem Iron Company tested in the former trials. Their value for comparative purposes was somewhat lessened by the fact that neither was up to the proper dimensions. They should each have been 10½ inches thick with a superficial area of 8 x 6 feet. The steel plate was warped in tempering, and in order to get a flat surface for securing it to the backing it was planed down so that its thickness at the sides was reduced about an inch. The reduction at the points of impact was not so great. The nickel-steel plate was cracked at one end, and about twenty inches were cut off, reducing it almost to a square. Owing to this reduced area, but four shots were fired at it instead of five, as at the other plates. Three six-inch shots were fired so as to form an isosceles triangle with its apex two feet below the centre of the upper edge of the plate, and the base angles two feet from the bottom and two feet from the right and left-hand sides, respectively. The fourth shot was from the eight-inch gun at the centre of the triangle. The points of impact on the steel plate were the same as in the six plates previously tried—a six-inch shot at each corner and

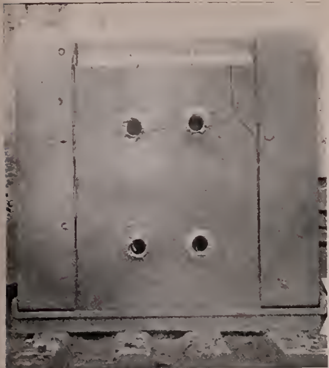


FIG. 23.—Harvey low-carbon steel, Carnegie.

FIG. 24.—Harvey low-carbon steel, Carnegie.

FIG. 26.—Harvey high-carbon nickel steel, Carnegie.

FIG. 28.—Harvey high-carbon nickel steel, Carnegie (back).

FIG. 27.—Harvey high-carbon nickel steel, Carnegie.

FIG. 29.

Harvey low-carbon steel, Carnegie. Harvey high-carbon nickel steel, Carnegie.

an eight-inch shot at the centre. All the conditions of the trial were as before.

Round 1.

The first shot was at the upper right left corner of the steel plate, which was completely perforated, with a total

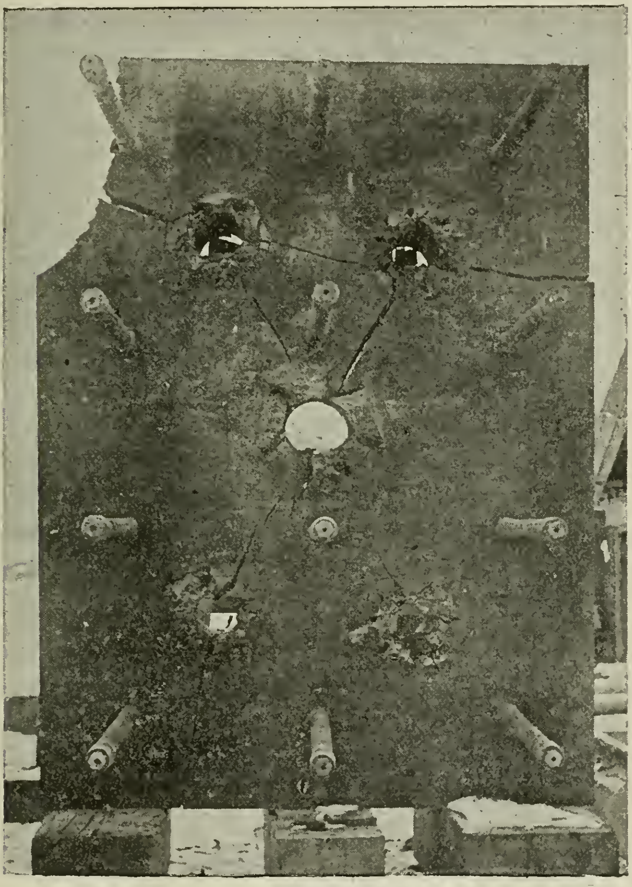


FIG 25—Harvey low-carbon steel, Carnegie (back).

penetration of thirty-nine and one-half inches. The plate was not cracked. (*Figs. 23, 24, 25* and *29*.)

Round 2.

First shot at the apex of the triangle in the nickel-steel plate. The projectile penetrated eleven and one-half inches,

and rebounded slightly broken, leaving an irregular hole from which chips of metal flew over the bomb-proof and far out into the Potomac River. No cracks were visible. (*Figs. 26, 27, 28* and *29*.)

Round 3.

Second shot at the upper right-hand corner of the steel plate. It penetrated thirty inches in the plate and backing, and cracked a triangular piece off the upper right-hand corner of the plate with a crack connecting this fracture with the shot hole. (*Figs. 23, 24, 25* and *29*.)

Round 4.

Second shot at the lower right-hand angle of the triangle on the nickel-steel plate. It penetrated thirteen inches, leaving another ragged hole from which there was another shower of chips. There was still no crack in this plate. (*Figs. 26. 27, 28* and *29*.)

Round 5.

Third shot at the lower left-hand corner of the steel plate, and penetrated thirty-five inches in the plate and backing. The previous cracks were widened, and a new crack developed between the two upper shot holes. (*Figs. 23, 24, 25* and *29*.)

Round 6.

Third shot at the lower left-hand angle of the triangle on the nickel-steel plate. It penetrated eleven inches and remained intact in the shot hole. A slight crack extended to the side of the plate. (*Figs. 26, 27, 28* and *29*.)

Round 7.

Fourth shot at the lower right-hand corner of the steel plate. It penetrated the plate and backing forty-three inches, and a new crack was opened up from the upper left-hand hole to the left edge. (*Figs. 23, 24, 25* and *29*.)

Round 8.—Eight-inch Gun.

Fifth shot at the centre of the steel plate. It went clear through the plate and backing, struck the sand bank behind

them and glanced over. It was picked up uninjured. (*Figs. 23, 24, 25* and *29.*)

Round 9.—Eight-inch Gun.

Fourth shot at the centre of the nickel-steel plate, which had been so weakened by the three shots already grouped so close together that it was wrecked. The projectile encountered so little resistance that it went on into the sand mound. Cracks from two inches to three inches extended from the centre through each shot hole to the edges. (*Figs. 26, 27, 28* and *29.*)

It is very clear from the above results the steel plate was very inferior, being little or no better than the compound plate tried at Annapolis in 1890.

The penetrations in the nickel-steel plate were eleven and one-half, thirteen and eleven inches for the six-inch projectiles, a slight crack being developed at the third shot.

Considering the disadvantages, as compared with the previous tests under which this plate was tried, it certainly made a very good defence, and probably if of the same dimensions and tested in the same manner, would have made as good showing as the similar Bethlehem plate.

The same peculiarities as regards the chipping of the metal about the points of impact, will be observed in these plates as in all the others treated by the Harvey process.

Methods of Hardening the Surface of Armor-plates.—Within the last few years two methods have been suggested for producing an intensely hard face upon steel, alloyed-steel or compound armor-plates. Several other schemes for producing a similar result have been proposed, but the only ones that have in any way been successful, are the Harvey, and the Tresidder processes. The former, an American, and the latter a British adaptation of two old and well-known devices for superficially hardening steel, viz: in the Harvey process, hardening by cementation, and in the Tresidder, by quenching with a spray or sprays of water.

The function and desirability of this extra hard face is sufficiently obvious when we consider the well-known fact when a projectile enters a certain distance into an armor-

plate, it receives great support from the surrounding mass of metal, so that any resistance offered to it when it has half buried itself is very much less effectual than if applied to the surface.

This simple fact accounts for the failure of compound armor composed of a hard steel plate sandwiched between soft iron and steel plates. It has been found that a projectile which was unable to penetrate a hard steel plate under ordinary circumstances would do so if a layer of wrought iron was added to the *front* of the steel face.

The aim of these two processes is precisely the same, but the means quite different. For the sake of brevity we may consider the change in the Harvey as chemical, and in the Tresidder as molecular, although as a matter of fact there is probably a combined chemical and molecular change in both cases.

Harvey Process.—This process was patented in 1888, improved and strengthened by subsequent patent in 1891.* It is described in the patent specifications as follows:

"The armor-plate having been formed of the desired size and shape from a comparatively low steel, such as Bessemer steel or open hearth steel, containing (say) ·10 to ·35 per cent. of carbon, is laid, preferably, flatwise upon a bed of finely powdered dry clay or sand deposited upon the bottom of a fire-brick cell or compartment erected within the heating chamber of a suitable furnace. The plate may be so embedded that its upper surface is in the same plane with the upper surface of those portions of the bed of clay or sand which adjoins the sides and ends of the plate, or the plate may, if desired, be allowed to project to a greater or less distance above the surface of the clay or sand. In either case the treating compartment is then partially filled up with granular carbonaceous material, which, having been rammed down upon the plate, is covered with a stratum of sand, upon which there is laid a covering of heavy fire-bricks. The furnace is then raised to an intense heat, which is kept up for such period of time as may be

* U. S. Patents 376,194, and 460,262.

required for the absorption by the metal adjoining the upper surface of the plate of (say) an additional one per cent. (more or less) of carbon; or, in other words, the quantity of carbon, in addition to that originally present, which may be necessary to enable the said metal to acquire the capacity of hardening to the desired degree. The temperature of the heating chamber outside of the treating compartment is brought up to a height equal to or above that required to melt cast iron, and is kept up for a greater or less length of time, according to the depth of the stratum which it is intended to charge with an excess of carbon. This period, however, will, of course, vary according to the efficiency of the furnace.

"The degrees of efficiency possessed by different furnaces can only be satisfactorily ascertained by actual trial. When ascertained, the reproduction of given results merely requires the re-establishment of the conditions as to time and temperature under which said results have been previously observed to be obtained. This involves merely the maintenance of the furnace at a heat sufficient to melt cast iron for the period which by previous observation has been ascertained to be the period required for adding to the tenacity of the steel and for the supercarburization of the plate to the prescribed extent and depth. For example, a plate (say) ten and one-half inches in thickness, composed of a comparatively low steel containing (say) ·35 per cent. of carbon, may be charged with additional quantities of carbon, gradually varying in amount from (say) one-tenth of one per cent. at a depth of three inches beneath the surface of the exposed side of the plate to one per cent. at the surface thereof by a continuance of the treatment for a period of (say) 120 hours after the furnace has been raised to the required temperature.

"The statement that the heat at which the furnace is maintained is sufficient to melt cast iron is to be regarded as approximate merely. The more intense the heat the better, and while it will, of course, be understood that the longer the treatment is continued the greater will be the depth to which the carbon penetrates beneath the surface

against which the carbonaceous material is packed, it is also to be remarked that the penetration of the carbon is greatly facilitated by the continuous firm compression of the carbonaceous material against the plate. As a general rule, the thicker the armor-plate the greater will be the permissible depth of supercarburization. A ten-and-one-half-inch plate and a depth of supercarburization of three inches are herein referred to merely for the purpose of illustration. After the conclusion of the carburizing treatment the plate is taken out of the furnace, and without removal of the carbonaceous material from its surface, is allowed to cool down to the proper temperature for chilling. During the cooling operation the carbonaceous material protects the hot supercarburized surface from the air, and thus prevents the formation of scale, which, if present, would interfere with the subsequent hardening of the metal beneath it. The carbonaceous material, however, may without injurious consequences be temporarily removed from and quickly replaced upon small portions of the supercarburized surface for the purpose of exposing them for observation. When it is seen that the supercarburized surface is so far cooled down as to have a dull cherry-red color, the carbonaceous material is quickly removed, and the plate is then chilled by being sprayed with torrents of cold fluid or by being submerged and kept in motion until cold in a large body of cooling fluid.

"*Fig. 30* is a transverse vertical section of the furnace, showing the armor-plate and the cell or compartment containing the bodies of material in which the armor-plate is inclosed. *Fig. 31* is a transverse section of a portion of an armor-plate shaded to symbolically represent variable degrees of supercarburization at different depths beneath the surface upon the side intended for exposure to the impact of projectiles. In *Fig. 30* the furnace *A* is represented as provided with a movable cover *A'*, or it may be constructed with reference to having one or both of its end walls removed to facilitate the removal of the plate in a horizontal direction.

"Within the heating chamber A^2 of the furnace is the

treating cell or compartment *B*, which is preferably provided at the bottom with a series *b* of parallel rails, which are embedded in a stratum of sand *C* of the same height as the rails and are intended for the support of the armor-plate *D*. The space around the ends and sides of the armor-plate is also filled with sand *C′* nearly or quite to the top of the plate. A stratum of granular carbonaceous

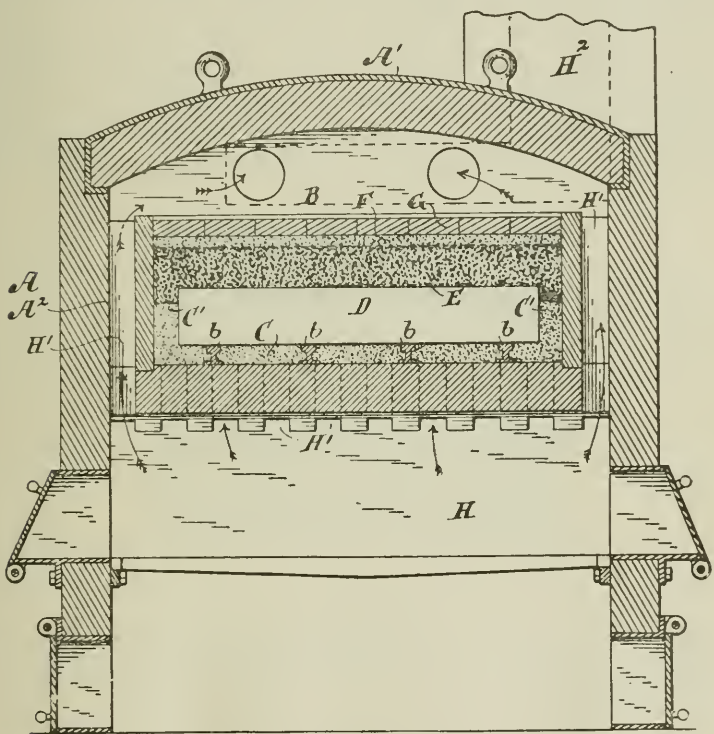


FIG. 30.

material *E*, rising to a height of (say) eight inches above the upper surface of the plate *D*, is tightly rammed down on to the top of the plate and is surmounted by a stratum of (say) two inches of sand *F*, covered by a layer *G* of heavy fire-brick. The stratum of sand *F* and the layer of fire-brick *G* not only protect the carbonaceous material from the fire, but also serve to weight the carbonaceous material down upon the plate."

The treating compartment *B* is heated by the flames and hot products of combustion from the fire chamber *H*, which are led upward through the flues *H* and directed inward over the tops of the treating compartment and finally discharged into the chimney or smoke stack H^2.

The carbonaceous material referred to is probably charcoal, although it is likely other substances have been tried. The length of time necessary to effect this carburization is probably nearer two weeks or 336 hours, than 120 hours as stated. Of course the length of this period depends largely upon the size of the plate treated; it seems the 8 x 6 feet by 10½ inch plates tested at Indian Head required two weeks or more. It must be remembered, however, the process has

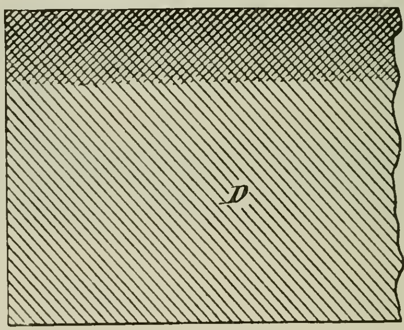


FIG. 31.

by no means been perfected, and there can be no doubt this period of time will be materially reduced in treating the larger plates.

A great difficulty met with in treating armor-plates by the Harvey method, is their tendency to warp or twist during the operation or in the subsequent quenching and tempering. This difficulty is not, however, peculiar to the Harvey treated plates and will be doubtless overcome as it has been in other cases.

Another objection urged against the Harvey method of treatment does not appear to be so serious. When iron or steel is subjected to the intense heat of the carburizing atmosphere of a cementing chest or furnace, certain chemi-

cal reactions appear to take place in the interior of the metallic mass by which gases and gaseous compounds are liberated.

Percy states,* these gases are probably due to the reduction of part of the protoxide of iron, with the evolution of carbonic oxide. While this might be true with wrought iron containing intermingled slag or cinder, it seems possible but to a very slight degree with steel produced by casting into an ingot.

It would seem out of place in a paper of this character to enter into a discussion of these most interesting chemical phenomena; we know from the researches of Müller and others† that steel under most all circumstances contains considerable quantities of the gases hydrogen, nitrogen and carbonic oxide.‡

Furthermore, we know that when steel is highly heated portions of these gases and gaseous compounds escape from the metal; it is therefore easy to imagine how the blisters may be formed by the gases rising to the surface of the metal but not quite breaking through its outer skin or layer.

The formation of these will obviously decrease the thickness and homogeneity of the hardened face of the armor-plate and if any depth below its surface must somewhat decrease its ballistic resistance. It is difficult to see how this obstacle can be overcome in the manufacture of the plate; even compressed steel will evolve some gas when heated. It is difficult to see, however, how these blisters can be considered a serious drawback to the efficiency of an armor-plate unless they are at a considerable depth below the surface, which is not often the case.

As we have already seen the Harvey process is essentially a cementing one, the additional hardness given by it to an armor-plate being produced by a superficial increase of its content of combined carbon. This increase does not extend far into the steel, as the amount of carbon thus added, appears to vary inversely with the depth.

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* *Iron and Steel*, p. 772.

† See Howe's *Metallurgy of Steel*, p. 105, *et al.*

‡ *Iron*, 1879, p. 649; also 1883, pp. 51, 244 and 245.

The following analyses give the varying amounts of carbon in two steel rails treated by the Harvey process. The idea is to make the top of the rail, which is exposed to wear, hard, whilst the balance of the rail remains soft and not subject to danger from breakage.*

Depth. Inches.	Amount of Carbon. No. 1. Rail.	No. 2. Rail.
$\frac{1}{16}$	0·76	0·76
$\frac{1}{8}$	0·42	0·42
$\frac{3}{16}$	0·33	0·31
$\frac{1}{4}$	0·30	0·30
$\frac{3}{8}$	0·30	0·30
$\frac{1}{2}$	0·33	0·30
$\frac{5}{8}$	0·30	0·27
$\frac{3}{4}$	0·30	0·28
1	0·27	0·26
$1\frac{1}{4}$	0·27	0·26
$1\frac{1}{2}$	0·27	0·25
Flange,	0·24	0·27

The hard face of the Harvey treated Bethlehem steel plate of the Indian Head trials of October 31, 1891, showed by analysis the following composition: †

	I.	*II.*
Combined carbon,	0·58	0·56
Graphitic carbon,	0·08	0·05
Phosphorus,	0·043	—
Manganese,	0·498	—
Silicon,	0·093	—
Sulphur,	0·019	—
Specific gravity,	7·845	—

While the Harvey process has in a measure accomplished the object for which it was designed, it seems to the author its present status cannot be considered satisfactory. It is at the best an exceedingly difficult and cumbersome operation to superficially cement and then to quench and temper such large masses of metal as ten and twelve-inch steel armor-plates. The time required to accomplish the object is great and the cost must be excessive, besides, the

* *Iron Age*, January 21, 1892, p. 118.

† The author is indebted to Mr. James S. de Benneville of Dr. Genth's laboratory for this analysis.

results obtained are uncertain and unreliable, as the plates may warp or blister to such an extent as to be worthless for defensive purposes. The process will undoubtedly be improved, for as the author has remarked before, many of the obstacles to its successful operation are mechanical. To the author's mind such cumbersome operations for hardening armor-plate seem essentially wrong; it seems to him the properties which produce the hardening effect should be inherent in the metal itself, and whether it be in the ingot or finished state these properties should remain latent until developed in quenching and tempering. Whether such properties exist in ordinary high-carbon steel or nickel-steel armor-plate and can be developed by such methods of quenching as the Tresidder process, remains to be seen. The Tresidder process certainly appears to have met with sufficient success to cause it to command our most careful consideration, although the description of its details, and the results obtained by its application so far made public are exceedingly limited.

Tresidder Process.—This improved system of quenching appears to be covered by the two British patents, 5,551, of 1891, and 22,177, of 1891, granted to T. J. Tressider, late Captain of H. M. Royal Engineers. It is stated in the specifications that the invention was suggested by the apparently unsatisfactory action of a water bath in hardening large masses of steel, due chiefly to the formation of a steam envelope round the immersed article, which envelope being continually broken and re-formed during the early stages of quenching, only allows the heat to be abstracted spasmodically instead of with the uniformity which is the first requisite for a successful result; that the superior action of an oil bath is due not to the chemical composition of the oil but to the absence of this steam envelope; and that the improvement in the action of a water bath due to the addition thereto of glycerine, or of any substance tending to raise the boiling point, is to be explained in the same way.

The object of the invention is to so apply water in quenching steel that the formation of a steam envelope

shall be impossible; but the invention is not limited to water alone, as any fluid or gas may be applied in the same manner.

It is claimed that the result of this method of quenching is to produce an intense superficial hardness in the surface of compound, steel or alloyed-steel plates, as well as increased tenacity and toughness, such as has hitherto been obtained by oil quenching and annealing.* The injurious and commonly fatal internal strains produced by ordinary water quenching are entirely avoided in this method.

The method of procedure is very fully stated by Capt. Tresidder in British patent 22,177, 1891, from which we quote at length:

"If the plate to be treated is a compound plate, I make it and machine it in the usual way except that I use false templates to which to bend it. These false templates are constructed from the designer's templates, as will be described further on. When the plate is finished as far as regards all machine work to the steel portion, all holes (if there be any, such as those tapped in the top edges of belt plates for the deck attachment), in the steel, are plugged with flush wrought-iron screw plugs arranged so as to be withdrawn with facility, similarly any keyways in the edges, if in the steel portion, are fitted with temporary keys. The plate is then carefully heated in a furnace to a 'hardening heat' which will, of course, vary with the nature of the steel; ordinarily a moderate red heat will suffice. When hot enough it is taken from the furnace and deposited steel side up on four supports in a large flat tray (*Fig. 32*) in such a way that the edge of the tray is everywhere a little higher than the bottom of the plate. An apparatus, which I call a douche, consisting of a system of pipes, perforated with a large number of small holes, in connection with water supply (*Figs. 32* and *33*) is then brought up and supported a little above the plate, and the water is turned on. At first the water quenches the steel side only, but in a few

* Although it is not stated in the patent specification, high-carbon steel or nickel-steel is presumably included.

moments the tray becomes full and forms a bath to the lower iron side. The object of this is to reduce the warping of the plate, which it does by about one-half; it also tends to assist the chilling action of the douche above, but the soft iron on which it acts is not affected.* If the utmost

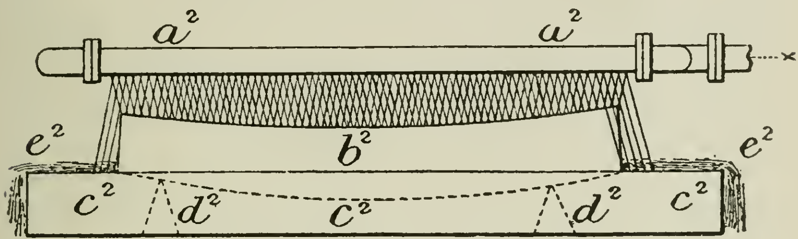

FIG. 32.

possible degree of hardness is desired the douching is continued till the plate is cold, but I sometimes stop the water after all redness has disappeared, throw on the plate some scraps of soft alloy, and turn on the water again as soon as these scraps show signs of melting. In this way, by using

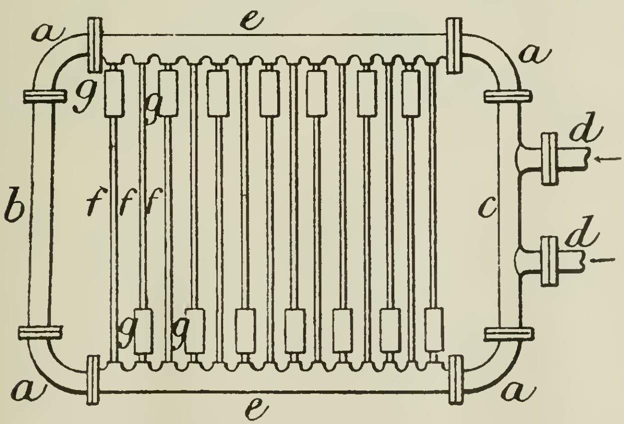

FIG. 33.

alloys of suitable melting points, the plate can be tempered with great nicety to any required degree. When the plate is cold it will be found to have its proper finished shape if

* This description applies to compound plates, but as we have stated the invention is not confined to this type of plate. F. L. G.

the false templates have been correctly made and worked to. The temporary plugs and keys (if any) can then be withdrawn and the bolt holes drilled and tapped in the back to complete the plate. No correction whatever of the edges should be required, but if a little proves necessary I employ an emery wheel mounted in the tool box of a planing machine, and independently driven, as a planing tool. In order to prevent too great rapidity of cooling at the corners of the plate I sometimes attach thereto iron shoes (*Fig. 34*) which modify the chilling action of the water at those parts. In special cases the edges of the plate also may be protected in a similar manner even to the extent of keeping them soft enough to be machined (*Fig. 34*).

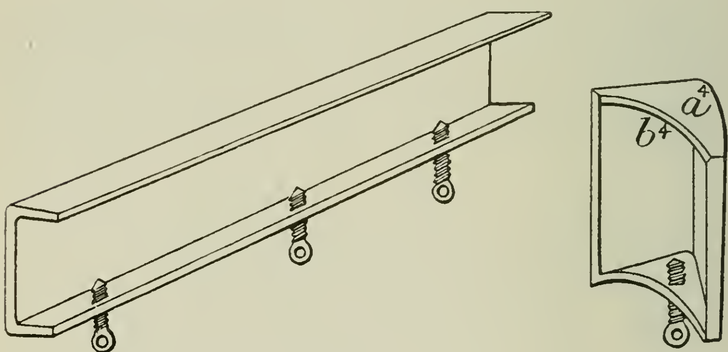

FIG. 34.

"If the plate to be finished is a compound plate (steel face and iron back) to be finished with considerable curvature (as a turret or conning tower plate, etc.), I proceed exactly as described above except that instead of a tray I use a second douching apparatus to cool the under side of the plate (*Fig. 35*). This acts upwards, but it must be remembered in all cases that the douche which is to harden the plate is at its best advantage when acting directly downwards.

"If the plate to be treated is a compound steel plate in which the back is of so mild a nature as to undergo water quenching without losing toughness, the double douche as described for a curved compound plate may be used; but if

it is undesirable to quench the back then the downward douche on the face only, without any tray to hold the water up against the back, is to be preferred. In this last case the false templates will require to be differently designed, as described further on. Another method is to use the double douche with water above the plate, and air or wet air below."

(4) If the plate to be treated is a homogeneous steel plate requiring toughness throughout rather than a hard face, either the double douche or the single douche with tray will be efficient, and false templates are not very important in such a case since the plate can be "set" after treatment without heating. But in a case of this kind I prefer to use a double douche of a wet air applied in the same way as

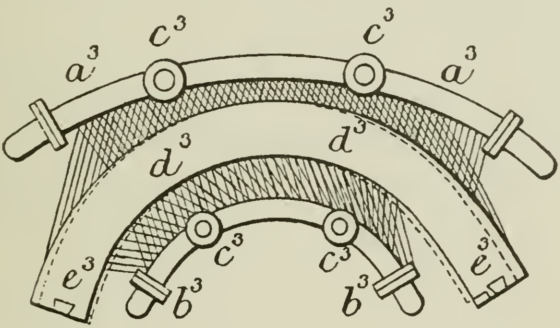

FIG. 35.

the water. The air is wetted by passing through a chamber into which tiny jets of water are allowed to play or by the method, described in my patent 12,347 of 1887, and it then passes into a box one side of which is full of perforations or into the same douche as described for use with water or other fluid.

"Repeated experiments have shown that the warping produced by quenching a straight plate nine or ten inches thick from one side only is of a uniform convexity towards the quenched side, and that the amount of convexity is about three-eighths inch in a distance of four feet; also that the warping of a steel-faced compound plate of the same thickness quenched from both sides is similar in nature, but less in extent being at the rate of about one-fourth inch in

distance of four feet. Homogeneous steel plates equally quenched from both sides after being uniformly heated have no tendency to warp. Experiment has also shown that by bending a flat plate till it is concave on the side to be hardened to an extent determined in the manner above specified, its flatness will be restored by the warp due to quenching. Thus plates to be treated by this process must be originally bent with less convexity on the hard side than ultimately required, and the proper form for the false templates previously alluded to can be arrived at approximately by applying one of the corrections given above and with accuracy after a few trials with the particular kind of plate to be treated. Thin plates warp more than thick ones. A plate four inches thick shows a convexity of one-half inch in four feet when hardened on one side.

"As regards the water pressure to be used I prefer a high pressure, say eighty pounds to the square inch, but this depends greatly upon the area of the surface to be treated; in any case there must be sufficient volume of water to cause a brisk flow from all the apertures of the douching apparatus. For the air or wet air quenching a pressure of about ten pounds to the inch will suffice.

"The action of the water douche on high carbon steels is, as might be expected, to produce intense hardness. As the carbon is lower, the hardening becomes less marked, but an appreciable hardening or stiffening effect is produced with steels containing as little as two-tenths of one per cent. of carbon. In such a case the effect of the treatment resembles that obtained by hardening a steel of somewhat higher carbon in oil at about 1,500° F., and then annealing at about 900° F. The wet air has a milder action (on large masses) about that of oil hardening at 1,300° F., and annealing at 1,200° F. Dry air, especially hot dry air, has the mildest effect of all, but the uniform distribution of the cooling action peculiar to this invention always results in improving the steel."

It seems rather odd that the application of this kind of device to armor-plate should be patented at this late day. A number of years ago Jarolimek mentions the difficulty of hardening steel in water, owing to the formation of a film of

steam on the surface of the heated metal, and suggests the use of jets and sprays as obviating to a great degree the difficulty.*

He particularly recommends a fine spray of water produced by means of an air blast, and states "this apparatus affords a mixture of air and fine particles of water, which strike with great velocity against the hot steel, the result is not only a rapid conversion into steam, but the steam formed is quickly carried away, so that it is possible to obtain extraordinary hardness and, what is more important, a uniform hardness in the steel."†

The degree of hardness obtained will, of course, depend greatly upon the amount of carbon present, the lower the carbon the more rapid and violent the cooling must be to produce the hardest effect possible. Pure cold water is undoubtedly the best substance for producing the hardness so essential to armor-plate. When applied in the manner described by Capt. Tresidder, its maximum efficiency in rapid cooling is probably reached, besides, in order to produce a uniformity of hardness it is essential that the quenching should be coincident over the entire surface of an armor-plate. These requirements the Tresidder method appears to meet, and it seems likely it will give good account of itself in the near future.

The results of the only important trials of Tresidder treated plates which have been made public are those of the *Nettle* trials at Portsmouth, October 2, 1891. Some experimental plates were tried at Shoeburyness during the summer of 1891, but the results obtained were not as important as the more recent ones.‡

The Tresidder treated plate tested at Portsmouth was made by Brown & Co., of Sheffield, on the Ellis system of making compound plates. It was of the usual dimensions,

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* The efficiency of a water spray or douche in hardening tools is well known. F. L. G.

† *Metallurgical Review*, No. 1, 1877–1878, pp. 157, 158.

‡ *Engineer*, November 6, 1891, p. 374. *Engineering*, November 6, 1891, p. 543.

8 x 6 feet by 10½ inches, and weighed 9·4 tons. The conditions of the trial were as follows: Gun B. L., six-inch; powder, 48 pounds; projectile, 100 pounds; range, 30 feet; striking velocity, 1,950 f. s.; striking energy, 2,637 f. t.; energy of each blow, 288 f. t. per ton of plate. Rounds 1, 2 and 5 Holtzer a. p. projectiles; rounds 3 and 4 Palliser chilled iron projectiles—no eight-inch projectiles were used.

It will thus be noted while many of the conditions are similar, the test was much less severe than those of the

FIG. 36.

Annapolis and Indian Head trials, where all the six-inch projectiles were Holtzer steel, and in all cases an eight-inch projectile was fired into the centre of each plate.

Round 1, at lower right-hand corner, projectile broke up, bulge on back 0·4 inch; two cracks developed (*Figs. 36* and *37*.) Round 2, upper left-hand corner, projectile broke up; bulge on back 0·9 inch, several cracks developed. Round 3 (Palliser), upper right-hand corner, projectile broken up; bulge at back 0·6 inch. Round 4 (Palliser), lower left-hand corner, projectile broken up; bulge at back

0·3 inch. Round 5, centre, projectile broken up; bulge at back one inch, numerous cracks developed.* (*Figs. 36* and *37*.)

A rather marked peculiarity observed in some of the plates at the Indian Head trials was the apparent difference in the resisting power at the several points of impact on the same plate. Thus in the Carnegie low-carbon nickel-steel plate (*Figs. 10, 11* and *14*) the penetrations of the

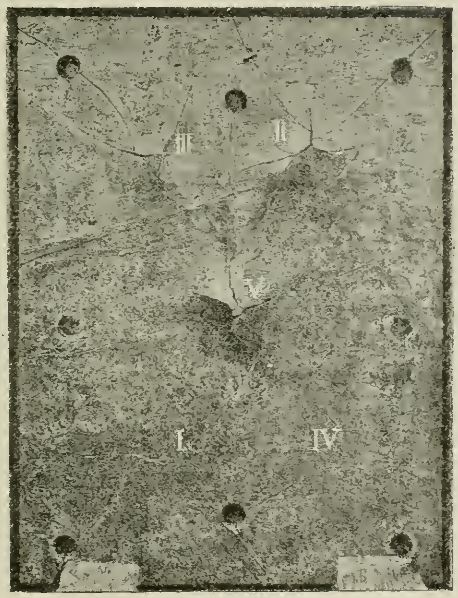

FIG. 37.

upper two six-inch projectiles was 26·5 and 26·3 inches whilst the lower two were only 14·6 and 13·1 inches. A similar peculiarity was observed in the Harvey high-carbon nickel-steel Bethlehem plate; in this case the penetrations on the right-hand side of the plate were 6·8 and 7·3 inches, on the left twelve and twelve and one-quarter inches, showing one side to have about half the resistance of the other. It will be noticed from *Plate II* and the preceding table, the

* *Engineer*, November 13, 1891, p. 397. *Engineering*, November 13, 1891, p. 571.

penetration of the third snot on the Harvey low-carbon steel Bethlehem plate was 26·96 inches, being about two and one-half times greater than the other six-inch projectiles penetrations on the same plate. Again, in the case of the Harvey low-carbon nickel-steel Carnegie plate the fourth six-inch projectile penetrated 20·5 inches or about one-fourth more than the other six-inch projectiles on the same plate. (See *Figs. 17*, *18* and *22*.)

A somewhat similar irregularity was observed in the previously mentioned Brown compound plate treated by the Tresidder process. (See *ante*, and *Figs. 36* and *37*). The lower part of this plate appearing to be considerably harder than the upper.

It is likely the irregularities in the last two Harvey treated plates are due, in part at least, to a want of uniformity in the supercarbonized or hardened face.

In the two previous cases, however, this cause could hardly account for the great and what one might term a regular irregularity or difference in ballistic resistance.

It has been unofficially stated that this regular difference in resistance at the two sides or ends of the same plate was due to the manner of quenching; that the plates were lowered into the oil bath sideways or endways, as the case may be, and as a consequence but a small portion of the oil could come in contact with the heated metal at the same instant. The oil thus becoming locally or highly heated it could not produce the same chilling effect on all parts of the plate.

This difficulty is readily overcome, however, by lowering the plate into the oil or water-bath, as the case may be, face downwards so that the chilling effect takes place practically at the same moment over its entire surface.

The author understands this was done in the case of several of the plates at the Indian Head trials. The penetrations in both of the high-carbon nickel-steel plates were certainly comparatively uniform.

Under ordinary circumstances the degree of hardness, imparted by quenching is dependent upon three conditions, viz: the amount of carbon present in the steel; the differ-

ence of temperature between the heated metal and the fluid employed, or the rapidity with which the cooling takes place.

The problem now before steel armor-plate makers is to produce the greatest degree of hardness and elasticity with the least amount of carbon, because the greater the amount of carbon in the steel the more difficult it is to work.

Cumbersome methods for increasing the content of carbon and consequently the hardness, are not desirable. It seems safe to assume that the maximum hardening effort of the carbon usually present in the steel is seldon or never developed by the common methods of quenching armor-plate. Large masses of steel can never be hardened to the same degree as a small tool, for instance, by a simple immersion into a cooling fluid. Apparently the lower the carbon the more rapid and violent the cooling should be to yield a maximum of strength and hardness.

The elasticity of the steel is to a certain degree regulated by the difference of temperature between the heated metal and the fluid employed. This difference should be great if harder steel with less elasticity is desired—and conversely.

These conditions can be modified by using a warm liquid for cooling, or one of high conductivity without changing the temperature of heating.

Oil quenching usually gives a higher tensile strength and elongation than water quenching. Oil or water quenching is sometimes apt to produce splits and cracks, and for that reason molten lead has been largely used in France.

With lead quenching the chilling effect is of course slight, but the cooling is very slow and regular, which for some reasons is very desirable. Some very hard steels can be quenched in lead which could not be treated successfully in any other manner.

The Société Chatillon et Commentry claim that their armor-plate tempered (quenched) by their lead bath system shows much greater resistance than the plates treated by the ordinary methods.*

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* *Le Genie Civil*, vol. xiii, pp. 22–24.

The claims made for this system of lead quenching are undoubtedly extravagant; such a slow and gradual cooling cannot harden the steel, but it will probably increase the elastic limit and elongation and possibly the tensile strength. The increase of these factors will, of course, tend to increase the ballistic resistance to a limited extent. A very hard face cannot be developed by this or any other system of quenching by immersion if steels or nickel-steels of the average composition (say 0·40 per cent. carbon and three per cent. nickel) are used.

The entire subject of quenching and tempering steels is a most troublesome one, and one, moreover, about which there is much to be learned. It is not particularly difficult to obtain a desired temper with small masses of steel, such as tools, etc., but in dealing with such large masses as armor-plate in which internal strains are easily set up, the problem becomes a most difficult one.

The thickness of armor cannot be increased beyond its present proportions unless the specific gravity of the material used be much less than that of steel. The improvements made in armor to meet the increasing power of the gun must, therefore, be in the line of hardness and elasticity; how this is to be accomplished, it remains for the metallurgist to determine.

THE CONSTRUCTION AND INTERIOR ARRANGEMENT OF BUILDINGS DESIGNED TO BE USED AS THEATRES.

BY C. JOHN HEXAMER.

[*Read at the stated meeting of the Institute, held Wednesday, May 18, 1892.*]

Ten years ago I read a communication before the Institute "On the Prevention of Fires in Theatres," which was generally applicable to the theatres of our country. I have been called upon by your Committee on Meetings to say a few words on the same subject to-night, but more specifically in regard to local conditions. My remarks of ten years ago appeared in the *Journal*, and the matter seemed of such importance to the Institute that a special committee, with myself as chairman, was appointed to investigate and suggest better features in our American theatres.

Although not as much good as we had anticipated resulted from our labors (embodied in a printed report), we at least had the satisfaction of knowing that many of our suggestions were adopted in the rating schedules of underwriters; some, which had been decried as impractical by stage carpenters, have been introduced, and are now regularly in use in a number of places of amusement. It is difficult to achieve progress of any kind where a decided material return is not in view for the money expended.

Allow me to rapidly make a few suggestions which are no longer novel, recapitulating much that I have said on former occasions, before proceeding to what is new and of local importance.

A theatre should consist of four separate and distinct buildings, like the Park Theatre, separated by substantial brick walls, rising above the roofs, all communication to be cut off by the best known fire-resisting means. [The Park Theatre is, however, not a fire-proof structure, although in its general plan the most rationally designed of all our Philadelphia play-houses, and should it at any time burn

down, do not accuse me of the statement that it was fire-proof!]

(1) There should be a fire-proof auditorium (as fire-proof office buildings are now constructed).

(2) A stage building.

(3) A fire-proof building for dressing-rooms, etc.

(4) A fire-proof storage room for scenery, properties, etc., with fire-proof doors.

The proscenium wall should rise well above the roofs of all the buildings, with an iron girder covered by a good non-conductor, relieved by an arch, the weight of the wall above being sustained by the arch, so that if the girder gives way, by exposure to the intense heat of a fire, the wall will remain in place. Designers and managers usually prefer to close off the stage opening, square at the top. Where this is not desired the girder should be dispensed with. The wall should cut the stage-floor with incombustible material. When several years ago the Academy of Music was improved I again made this suggestion (this had previously been decried as an absurdity and practical impossibility) which was carried out, and has been in use since without annoyance or inconvenience of any kind. The wooden stage floor was cut, the wall being "brought up" near the level of the stage floor, and was finished off on the top with a heavy coat of cement which, when dry, corresponded in color with the wooden floor, and is not noticeable from the auditorium. Instead of being disagreeable to dancers, I was informed by the late Mr. Higbee, that the "*premieres*," selected the smooth, hard cement pavement for their "*tour de force*." It is self-evident that where the wooden stage floor is unbroken by an incombustible barrier, fires will be transmitted *beneath the fire curtain* from the stage to the auditorium.

The curtain should be of real asbestos, not half cotton, with an interior network of strong, woven, pliable wire to give it tensile strength, and should slide in iron grooves, at least six inches deep on both sides of the stage, securely bolted into the masonry of the proscenium wall.

All of the four buildings should be provided with large,

separate exits to the open air. Every part of the auditorium should have separate exits, and the exit of one part should never be allowed to discharge into that of another.

All corridors should increase in width from the theatre to the open air.

All extra exits (fire corridors) should be marked as such in large, bold letters; should be lighted by oil lamps (not petroleum products; sperm or lard oil is recommended), and should be unbarred from the opening of the theatre until it is closed. Before the close of every performance, they should be opened, so that the extra exits may become known to the public.

All doors should open outwards (a precaution which is still neglected in some of our concert club halls).

Long rows of seats should not be permitted. Rows should be cut by aisles at short intervals.

Movable seats should not be allowed. Seats should be tightly screwed to the floor. Fixed chairs with a spring attachment, which throws back the seats when not occupied, are strongly recommended.

No scenery, properties, materials or impediments of any description should be allowed to remain in the corridors.

The fire-proof drop-curtain should be kept down at all times except during rehearsals and performances; after which it should be immediately let down, and not raised until a few minutes before the beginning of the next performance. The lowering apparatus should be so arranged that the curtain will be lowered automatically in case of fire.

Doors in fire walls should have stone sills, and should be tin-lined on both sides, constructed according to the underwriters' specifications, without springs or locks, so they can readily be opened.

Incandescent electric lights should be used throughout, and all others should be prohibited on the stage.

The system of lighting the stage should be separated from that of lighting the auditorium; each should have a distinct circuit. The system should be installed under the

direction of the electric light inspector of the Fire Underwriters' Association. An ordinance should prohibit theuse of lights until so approved, and the certificate of approval has been issued, and a fine of $1,000 for each offence should be imposed. Should managers be satisfied in placing electric lights like gas lights, and leaving them in place as they usually do the latter, there would be little danger from incandescent lights which have been inspected and passed; but electric lights are so easily moved, and the novel scenic effects which can be contrived with them are so tempting, that these are frequently rearranged and this practice becomes exceedingly dangerous when carried on by ignorant persons, therefore expert supervision is most necessary.

It seems clearly established that the recent Central Theatre fire was caused by a gas light, which would have been impossible had electric incandescent lights been used exclusively. It may not be uninteresting to quote here what we advocated ten years ago:

"The greatest number of fires are caused by the paraphernalia of illumination. The danger of coal oil, which is much used in our country and Western theatres as an illuminating agent, is self-evident, but the hazards of gas, which until within a few years was the safest material at ou command, are not so well understood. Besides the dangers of leakage and explosions, we have, in the case of illumination, hundreds of *flames* spread throughout a building, each forming a dangerous sphere around itself. Although the last-named dangers can and should be lessened by proper precautions, such as wire baskets and shields over the flames, still, when we consider the close proximity of the border lights to combustible gauzes and canvas, and ponder on the hazards of temporary illuminating effects, where jets are fed through rubber hose which must be removed during change of scene, we must ask is there no other method of illuminating by which equally good artistic effects may be produced, and which at the same time will lessen or entirely do away with the hazards of the present system? Fortunately means are now at hand. By the labor of eminent electricians, we have at our disposal an agent by which the

same, if not more brilliant, effects than with gas can be produced, while doing away with the dangers of gas, the lamps themselves being absolutely safe," etc.

Where electricity is generated in the theatre, the boilers, engine and dynamo should not be located in the stage building, and lights in stairways should receive their currents from outside independent sources.

A large reservoir, the bottom at least ten feet above the highest sprinkler, holding at least 5,000 gallons should be introduced. It should always be kept full of water, connecting with the standpipes and not allowed to freeze. (This can easily be accomplished by passing the exhaust steam pipe through it.)

Every theatre should be supplied with a sufficient number of fire hydrants, connected with the tank, with hose and nozzle attached ready for instant use and not removable. The tank connection is important as the city water pressure is so feeble in some districts (having been found by actual tests to be as low as twenty and twenty-six pounds), that it would be impossible to squirt to the top of the stage, with the appliances now in use in some play-houses.

The stage and workshops, and if there is an attic above the auditorium, this also, should be fully equipped with an approved system of automatic sprinklers, connected with two supplies, an approved pump and tank, both of which should be located outside of the stage building. Automatic apparatus is worthless unless in perfect working order, and should, therefore, frequently be carefully inspected, tested and reported upon. The following underwriters' report on the sprinkler system of one of our theatres will give you an idea how this should be done; also of the *necessity* of laws, official municipal inspections, and fines for neglect in these matters. [I withhold the name of the theatre.]

System; Wet Pipe; Equipment.—Full protection under roof, gridiron, fly galleries and stage.

Water Supply.—4,000 gallon tank on roof. Bottom of tank is elevated ten feet above highest sprinklers. Tank is filled by steam pump and has steam pipe inside.

Condition of Equipment.—Fair. Rising main is three inch.

Pipe sizes are correct. Check valve at tank to operate automatic alarm, which is located on stage and in good order. Pet cocks in upper part of system. No city water or pump connections for supply. No hose attached to sprinkler system. Draw-off pipe approved.

Remarks.—The water in tank has been *repeatedly* found *low and frozen*, and *it is evident that proper attention is not given to the sprinkler system.* We therefore rescind the sprinkler allowance until further notice.

A sufficient number of fire buckets (used in case of fire only), kept always filled, should be distributed conspicuously over the premises.

Each theatre should have at least two firemen (one on each side of the stage).

Every play-house should be connected with the nearest fire station by electric alarms in the office and on the stage, the latter to be further thoroughly equipped with automatic alarms.

Theatres should be patrolled at day and night by watchmen, who should be controlled by electric watch-clocks, with stations distributed over various parts of the buildings, records to be kept on file for the examination of the inspector.

No smoking should be allowed in the theatre, except where required on the stage in the representation of plays.

Steam or hot water should be exclusively employed for heating.

Scenery and other stage supplies should not be stored on the stage, but in a separate fire-proof dock.

No more scenery should be put upon the stage than is necessary for, at most, two performances.

The use of fireworks, roman candles, red fires, etc., should only be permitted when it has been shown to the Theatre Inspectors' satisfaction that the scenery and gauzes have been impregnated by proper substances, and that the woodwork has been covered by some satisfactory solution.

Wads of pistols and guns should be of hair only—not paper or cotton.

If straw, hay or any other easily inflammable substance be required in a scene, it should be impregnated and

be removed to a fire-proof place immediately after the scene in which it is used.

So much interest was manifested in an exhibition of some "*fire-proofed*" (impregnated) substances and the results seemed to be so novel to many of those present that, perhaps, a few additional remarks may not be amiss. Ten years ago I wrote:

"The experiment of making certain pieces of decoration of an incombustible material has been tried many times, and with considerable success. Especially the flies, as being most exposed and hanging among the border-lights, have in some cases been made of fine wire gauze. The interstices were then filled with an incombustible substance, and the flies were then painted in the usual manner. This method certainly gives entire security against fire, and the greater amount of first cost is more than counter-balanced by their greater durability; but the inconvenience of handling such pieces is greatly increased by their greater weight, making them practically impossible for drops, and larger wings and flats."

Another device is to protect the wood and canvas by painting it with suitable materials, and thus to make it incombustible.

After the rebuilding of the Opera House at Munich (destroyed by fire, 1823), the wood-work was given a few coats of water-glass. This kept well for twenty years, but later trial showed that the coating of water-glass had changed its *chemical composition, and gave no further security.*

Water-glass is further objectionable on account of the gloss it imparts to scenery, thereby reflecting light, and spoiling the artistic effect of the painting.

The impregnation of scenery before painting has been strongly advocated, and especially of the aforementioned flies. Some of the different substances used for this purpose are alum, sodium sulphate, borax, the soluble fluorides, and calcium sulphate. It was claimed that by impregnation canvas became so far incombustible that it could neither propagate flames nor glow for any length of time, and even under great heat would only char.

After the fire at the Berlin Opera House the authorities ordered the soaking of all scenery in a solution of alum.

The same question was raised and given to a commission to decide some twenty-five years ago in Paris. On account of the report of this commission an ordinance was issued enforcing the impregnation of all scenery. This was carried into effect in several theatres until, unexpectedly, some impregnated gauze was set on fire by the heat of a candle. The mayor had the case investigated. It was found that the ingredients used had lost their protective power, and had changed the chemical composition of the paint.

The writer ascribes the failure of these experiments to the manner in which the process was conducted; the canvas being in all cases merely soaked in the solution and then dried and painted. If a piece of canvas is soaked in water-glass and allowed to dry, the liquid in losing its water will contract more and more, until finally the solid particles will sit loosely on the *yarn* of the canvas.

Again, sodium tetra-silicate (water-glass being soluble in water), is dissolved on coming in contact with water. The water-colors used in scene painting may therefore have dissolved the greater part of the silicate at the start.

To obviate this the author would suggest the following: After thoroughly soaking the canvas in water-glass it should be placed in a dilute solution of hydrochloric acid; this would precipitate the silica inside of the *fibres* of the yarn itself. The reaction being the formation of silica, sodium chloride and water; viz: $Na_2Si_4O_9 + HCl = 4SiO_2 + 2NaCl + H_2O$. The silica, being insoluble in water, could not be washed out, and, on account of its precipitation in the fibres, could not readily be thrown out, this process being a parallel case to the use of a mordant in dyeing; the linen in that case being first soaked in color, and this then precipitated (made fast) by the mordant. As silica has no gloss, this process would also get over that difficulty.

Of course, any other incombustible substance precipitated into the fibres will answer as well as the above.

Other solutions recently recommended for purposes of

impregnation are: Versmann's and Oppenheim's, who advise a solution of 2 parts of sodium tungstate with 3 parts of sodium phosphate; Nicoll, one consisting of 6 parts of alum, 2 parts borax, and 1 part dextrine dissolved in soap-water; Siebdrath uses 5 parts of alum, 5 of ammonium phosphate, and 100 parts water; Patera, 15 parts borax, 11¼ parts of sodium sulphate, and 100 of water; Martin (see later invention further on), 8 parts ammonium sulphate, 2½ of sodium carbonate, 3 parts boracic acid, 2 of borax, 2 of starch and 100 of water. And very recently it has been suggested to use a solution of magnesium chloride.

The combustibility of scenery is also greatly lessened by painting it on both sides, as the fuzz on the back of scenery, along which flames spread, is thereby destroyed, etc.

Scenery might be made much safer than it is by simply whitewashing the back of it, thus destroying the fuzz. This is an exceedingly cheap and simple operation, and there can be no excuse for not carrying it out, etc.

And in the later committee's report:

"The only manner in which the dangers of fireworks may be lessened is by "*impregnating*" all scenery and gauze by approved processes. Your committee has for the past six months experimented with all ascertainable processes of impregnation. A process which your committee has found to be deserving of entire public confidence is that of Dr. J. Pafen, of Frankfort, Germany.

"Satisfactory results have also been obtained by the processes of Gautsch and Judlin, by sulphate of ammonia, and by silica deposited in the fibres by precipitation.

Besides impregnating the scenery, the woodwork should be covered with some fire-proof paint. Your committee experimented with a large number of solutions, and had most satisfactory results from real 'asbestos paint,' and especially from the so-called asbestos concrete."

I will now add that the following processes are patented in the United States:

(1) Zapfle, No. 199,950, February 5, 1878.

(2) Mathes, No. 254,560, March 7, 1882.

(3) Bartlett, No. 300,190, June 10, 1884.

(4) Fröhlich, No. 310,404, January 6, 1885.
(5) Smith, No. 314,886, March 31, 1885.
(6) Konrad, No. 319,100, June 2, 1885.
(7) Martin, No. 331,312, December 1, 1885.
(8) Sornberger, No. 362,232, May 3, 1888.
(9) { McIntyre, No. 391,327, October 16, 1888.
McIntyre, No. 391,261, October 16, 1888.

The compositions of which are roughly as follows: (Those specially interested can readily look up more thoroughly the specifications in the institute library.)

(*1*) *Zapfle*—Hydrochloric acid (purified by chloride of barium), carbonate of lime, crystallized alum (with potassa base), chlorate of ammonia, borax and water.

(*2*) *Mathes*—2 parts soda, 1 part alum, ¾ part borax, ¼ part potash, 6 parts water-glass, and water.

(*3*) *Bartlett*—200 gallons water, 400 pounds sodic chloride, 200 pounds ammonium chloride, and a solution of 156 pounds carbonate of potash and hydrochloric acid, neutralized by 75 pounds of bicarbonate of soda.

(4) *Fröhlich*—Compound of silicate of soda, alum, sodium chloride and phosphate of ammonia.

(5) *Smith*—Sulphite or hyposulphite of soda with muriate of ammonia; common rock salt is added for incrustation.

(6) *Konrad*—Solution of sulphate of ammonia, carbonate of ammonia, borax, bichloride of mercury, peppermint, carbolic acid, bitungstate of soda, and chloride of lime, transformed into an emulsion by leading into the solution the products obtained from the distillation of a solution of Peruvian balsam and camphor in acetic ether.

(7) *Martin*—(Specimens of inflammable substances treated by this process were shown and tested at the meeting.) Glycerine, ammoniacal salts and fire-resisting and preservative substances. Specified as 2 parts by weight of glycerine, 1 carbonate of ammonia, 8 hydrochlorate of ammonia, ·8 soluble cream tartar, ·8 oxalate of potash, 8 boracic acid and water.

(8) *Sornberger*—1 gallon water, 1½ pounds chloride of

sodium, 1½ pounds chloride of ammonium, 10 to 30 grains potassium permanganate, 4 ounces sodic sulphate.

(9) *McIntyre*—Ammoniacal and preservative salts and sulpho-ricinoleate of ammonia.

I have had occasion to test the latter with good results. It is claimed that the sulpho-ricinoleate prevents the dropping out of the salts: which in case of the Martin process is accomplished by means of glycerine.

The trouble with most solutions has been that when the salts have, in the course of time, become thoroughly dried they drop out of the fibres; this can be prevented by using a hygroscopic substance in the compound, as glycerine in the Martin process, which, although in minute quantities, continues to absorb moisture from the atmosphere, thus preventing the absolute drying and disintegration of the salts. I can see no reason why other hygroscopic substances, such as calcium chloride, zinc chloride, etc., will not serve the same purposes as glycerine in such compounds.

Laws making the treatment of scenery in new theatres compulsory (as in New York), have not been successful. Although the "*stock*" scenery of a new theatre must be impregnated before the play-house is allowed to be opened; the travelling companies, with each piece, bring in materials which have not been treated, and which may cause a fire. The only remedy would be stringent laws and heavy fines against the *use* of *any* untreated materials.

A large smoke flue should be provided above the stage. Automatic devices are recommended. These and the reasons for their introduction I described in a former paper.

That the public itself may have control in this matter, a complaint book should be laid open to the public in every theatre, where any individual may enter faults of construction or arrangement which he has noticed. This book should not be the property of the proprietor of the theatre, but should belong to the Theatre Inspector, the Fire Marshal and Building Inspectors.

The workshops and paint loft should be outside of the stage building.

Ground plans of the auditorium, giving a clear idea of

the building, corridors, stairways, etc., should be prominently located in the halls, and should be printed on the back of programmes.

We all know by experience that any matter which devolves on a number of persons, especially when their time is fully occupied by other duties, is done badly, or not at all. As the old adage has it, "Everybody's business is nobody's business;" therefore, in order to keep control of the various theatres, a theatre inspector should be appointed, who should have full power to enter a theatre at any moment, and whose duty it should be to see that these or other suggestions, made law by ordinance of Councils or an act of Legislature, are faithfully carried out, to inspect watchmen's records, etc., test fire appliances, and once a month make a report on each theatre.

These reports should be kept on file by the Director of Public Safety, and can be used as evidence against managers, or against the inspector, should he become derelict in his duties.

I quote an Underwriters' Association report, in order to give a general idea how such reports should be made. (I purposely do not give the name of the theatre, which, since this inspection, has been somewhat improved.)

Date. . . . .

Report No. . . . . . .

Location. . . . . . .

Building and Fixtures.—Walls brick; roof tin and slate, mansard in rear; cornice wood, boxed; walls coped 5 feet lower than building adjoining on east; 12 inches between front communicating building and theatre on south; skylights thick glass, no screws; columns iron in galleries; galleries two; ceilings plastered; communication to front building, occupied by merchant tailor, gas burner company and offices and lobby of theatre; fire shutters and doors none; heating by furnaces well arranged; lighting, city gas, each section separated and controlled at gas table on stage; gas lighted by electric spark; border, foot lights etc., caged; proscenium, arch, frame; electric arc lighting in lobby and in front on street.

Fire Protection.—The fire protection consists of a three-inch stand pipe supplied by city main, with only one outlet which is in property room at rear of stage, 75 feet of good linen rubber lined 2½ inch hose attached to stand pipe by globe valve and Jones coupling; one cask for water each side on stage and one in flies on the prompt side; six metal fire buckets each side on stage and two each side in flies; running water on O. P. side of bridge; no buckets in auditorium; watchman nights and Sundays, no clocks; city water 27½ pounds pressure at 3 P. M.; smoking allowed only as the business of the play demands.

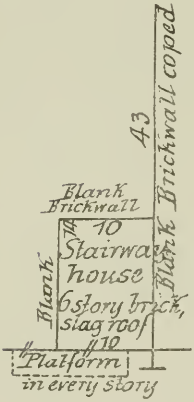
General Information.—No boiler; ashes loose; waste paper, sweepings and rubbish allowed to accumulate under stage; carpenter work done on stage; glue heated by gas on bridge safe; water colors only used for scene painting; scenery stored on stage; property and dressing rooms in rear of stage, separated by frame partition; water casks and fire buckets very much neglected; in one instance water cask had fallen apart for want of proper care.

The theatre building is in direct communication and one and the same risk with building where the merchant tailor tenant is using a gasoline pressure stove for generating steam in sponging cloth, carrying from one to five gallons of gasoline on second floor; the theatre building proper was originally an old stable. Building in fair repair; order and cleanliness poor; management fair.

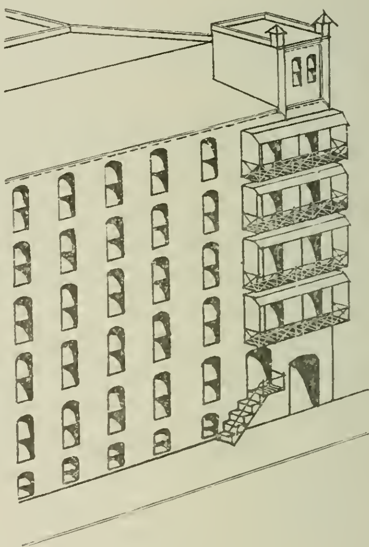
Improvements.—We suggest that all gasoline and gasoline stoves be removed from building at once; fire buckets and water casks to be regularly attended to and kept full of water; one dozen additional fire buckets be distributed in galleries on hooks; all waste paper and sweepings be removed from building, and under stage not to be used for a general receptacle for waste paper, sweepings and rubbish.

And now, in conclusion, permit me to touch another point, which, however, I do with some diffidence. Being a resident of the fifteenth ward I am fully imbued with the positive general necessity of the proposed $6,000,000 boulevard to the park. We are all in accord with the movement to create additional breathing spots in our city, and to

expend a large sum of money to beautify the surroundings of the bourse. But where, permit me to ask, are we more in need of open spaces than around our places of amusement where thousands nightly congregate? The only way in which theatres can be made safe is to place them fronting broad streets not less than 60 feet wide, with wide open spaces on both sides not less than 20 feet—30 would be better in width.



Plan.



View.

Then fire escapes, which are what the name implies, can be erected, and not arrangements the descent of which test the skill of an acrobat in broad daylight.

The best system of fire escapes is that of separated brick towers as introduced for permanent stairways in some of our well constructed manufactories. The above sections of a plan and bird's-eye view of one of our large local textile mills, shows how this is arranged, without requiring further verbal explanation.

I believe we have a right to require of our legislators that they prohibit the erection of additional fire-traps. But what shall we do with our present theatres? Force the

owners to make them safe as possible by ordinances or acts of Legislature, and let the city condemn the requisite adjoining properties, buy them, tear them down, and place breathing spaces on sides which are now without outlets. We never so long for a breath of fresh air as when in a building filled with smoke.

I have prepared ground plans of all the theatres of our city and surrounding properties. It will be seen on careful inspection of the plans before you, that the idea is not as extravagant as it appears at first utterance. Many of the theatres are at the intersections of streets needing but one side. The Board of Assessors could readily calculate what it would cost. The matter should be promptly acted upon. I believe, aside from the question of hazard from fire, it would be a good investment for the city. These spaces neatly kept, like little parks, would add much to the beauty of our municipality and would give the thousands who nightly attend our places of amusement, that greatest of all panaceas—pure air to breathe.

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, June 21, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 21, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Present, nine members.

In the absence of the author, the paper of the evening, "On the Composition of the Liquid Ammonia of the Trade, and how to Manufacture Liquid Ammonia of 99·995 Per Cent.," by Dr. Hans von Strombeck, of New York, was read by the Secretary.

The paper was discussed by Messrs. Bower, Hall and Terne and was referred for publication.

Adjourned. WM. C. DAY, *Secretary.*

ON THE COMPOSITION OF THE LIQUID AMMONIA OF THE TRADE AND HOW TO MANUFACTURE LIQUID AMMONIA OF REALLY 99·995 PER CENT.

BY DR. HANS VON STROMBECK.

[*Read at the stated meeting of the Chemical Section, June 21, 1892.*]

If the liquid ammonia of the trade, which is generally labelled and advertised as chemically pure anhydrous 100 per cent., is allowed to evaporate, a yellow fluid of peculiar penetrating odor and basic reaction is left in the bottle. This residue was left by any liquid ammonia which I subjected to the test, though they had been manufactured of different raw materials and by different processes. But the quantities left by different liquid ammonias were quite different. It is necessary to connect a long spiral cooler with the bottle in which the evaporation takes place and to

surround the cooler with a refrigerating mixture, as otherwise a large percentage of the yellow fluid is carried away by the evaporating ammonia. Sometimes also white needle-shaped crystals are left by the evaporating ammonia, which partly are deposited on the lower parts of the walls, partly swim on or are dissolved in the above-said fluid. These crystals consist of sesquicarbonate or hartshorn salt of ammonia $(NH_4)_2CO_3 + NH_4HCO_3$.

While this salt was present in every liquid ammonia analyzed, it did not appear in crystalline form every time. The basic reaction of the above-said yellow fluid is due to ammonia absorbed by the same. By supersaturation with dry muriatic acid, and removing the excess by quick-lime, a yellow neutral fluid is obtained. The yellow color is due to the presence of mineral (lubricant) oil. By distillation under reduced pressure, the latter can be separated out at 200 mm. pressure between 106° and 122° F., a colorless fluid being obtained in the receiver, while all the oil remains in the still. Besides by hartshorn salt of ammonia, by mineral oil and by "colorless fluid," as I shall call it in this paper, the liquid ammonia of the trade is contaminated by moisture and mineral matter suspended, the latter consisting of sand, peroxide of iron, etc. The mineral matter of sample B contained also sulphide of iron.

I give the analyses of six samples of so-called anhydrous liquid ammonia 100 per cent., manufactured of different raw material by different processes:

	A. per cent.	*B.* per cent.	*C.* per cent.	*D.* per cent.	*E.* per cent.	*F.* per cent.
Ammonia (by difference), .	98·976	96·984	98·220	99·792	99·321	99·180
Moisture, . . .	0·040	0·024	0·079	0·078	0·010	0·032
Colorless fluid,	0·950	2·880	1·644	0·117	0·622	0·666
Hartshorn salt of ammonia,	0·030	0·099	0·049	0·004	0·043	0·087
Lubricant oil, .	0·004	0·006	0·005	0·009	0·004	0·035
Mineral matter,	traces	0·007	0·003	traces	traces	traces
	100·000	100·000	100·000	100·000	100·000	100·000

The colorless fluid was further investigated. It has a specific gravity of 0·7948 at 60° F.; it is miscible with

water, burns with little luminous flame, has a specific odor reminding of alcohol and ketone. Subjected to distillation in fractions at atmospheric pressure (758 mm.), it yielded—

					Mainly consisting of
(1)	2·5 %	between 136° and 153° F.	specific gravity at 60° F.	0·8048	methyl alcohol and acetone ;
(2)	4·0	" 153° " 165°	" "	0·8077	methyl- and ethyl-alcohol ;
(3)	14·9	" 165° " 172°	" "	0·8016	ethyl- alcohol ;
(4)	78·6	" 172° " 180°	" "	0·7901	isopropyl alcohol.

The reaction for ketones was also given by fraction No. 2; traces could also be detected in fraction No. 3. The ketones present can only be acetone and methylethylketone. Besides also traces of ethers may be present.

The composition of different colorless fluids is slightly different, but if any of them or one of its fractions is brought into contact with metallic sodium, the whole mass at once congeals to a more or less reddish powder, hydrogen at the same time being evolved, according to the equation:

$$(1)\ \underbrace{CH_3.OH + CH_3.CO.CH_3}_{\text{Fraction 1.}} + \underbrace{CH_3.OH + C_2H_5.OH}_{\text{Fraction 2.}} + \underbrace{C_2H_5.OH}_{\text{Fraction 3}} + \underbrace{CH_3.CH.OH\ CH_3}_{\text{Fraction 4.}} + 2Na_2 =$$

$$CH_3.ONa + CH_3.CO.CH_2Na + CH_3.ONa + C_2H_5.ONa + C_2H_5.ONa + CH_3.CH.ONa.CH_3 + 2H_2$$

As to the constitution of the sodium acetone compound which is only of theoretical interest, I refer to *Liebig's Ann. Chem., 1891, 266, 1.*

If we suppose the fractions containing two different bodies to consist of equal parts of each, and calculate the hydrogen which ought to be evolved by the decomposition of one part by weight of colorless fluid by metallic sodium, we find that 0·0179 parts by weight of hydrogen ought to be evolved. By test I found as average of four determinations that one part by weight of colorless fluid evolves 0·0166 parts by weight of hydrogen or ninety-three per cent. of the calculated quantity. Taking into consideration that the supposition on which the calculation was based is somewhat arbitrary, a better agreement can hardly be expected. As one part by weight of hydrogen requires twenty-three parts by weight of metallic sodium for its evolution, one pound of colorless fluid requires 0·38 pound of metallic sodium for its transformation into solid sodium compound.

A reaction similar to that between colorless fluid and

metallic sodium takes place between the latter body and two of the other above-mentioned contaminations of liquid ammonia, viz: Moisture and hartshorn salt of ammonia according to the equations.

$$\text{(II)}\ 2H_2O + Na_2 = 2NaOH + H_2$$

and

$$\text{(III)}\ [(NH_4)_2CO_3 + NH_4HCO_3] + 2Na_2 = 3NH_3 + 2Na_2CO_3 + 2H_2$$

Based on the reactions which have been given in these three equations, I devised a process for the manufacture of liquid ammonia which on the average contains 99·995 per cent. of ammonia, 0·005 per cent. of mineral oil and nothing else (U. S. Patent 477,089), the removal of the oil being impossible because of its chemical nature. The process is as follows:

The ammonia gas which has been manufactured by one of the usual processes, and which has been already freed of the bulk of its moisture, instead of being directly drawn into the compressor, is first led through a vessel filled with molten metallic sodium. Here in this vessel the reactions described in the above three equations take place, whereby all contaminations present are transformed into solid non-volatile bodies and remain in this vessel, only ammonia gas and the hydrogen evolved escaping out of the same. The melting point of metallic sodium being at 204° F., it can easily be kept in a molten state by return steam which circulates through a jacket surrounding the vessel with the sodium. The ammonia is better led through two such vessels so as to make sure that all metallic sodium in the first one is exhausted before it is filled anew. By suitable connections the ammonia can be made to enter either vessel first or last. From the second vessel the now perfectly pure ammonia gas is drawn into the compressor and transformed into liquid in the usual way. From this description it will be seen that the apparatus required is of the simplest kind imaginable.

I first thought to bring the ammonia gas into contact with solid metallic sodium spread out on trays. But the reaction between the ammonia and the metallic sodium only

taking place as long as the surface of the latter is metallic, a somewhat complicated apparatus would have been required to meet this purpose. Knives and scoops would have had to be arranged in a drum in such a manner that the former continuously cut the metallic sodium to infinitesimally small pieces, while the latter carry them upward and drop them after they have reached an about perpendicular position, the ammonia gas thus having to pass through a constant shower of sodium with fresh metallic surfaces.

The hydrogen evolved is to be removed, as otherwise the engine working the compressor would have to perform useless work by the compression of the same. A very appropriate way to remove it is to have the purified ammonia gas and the hydrogen pass over palladium-black or palladium-gauze, each of which readily absorbs all hydrogen. Though palladium is a rather expensive article, one pound costing about $400, its expensiveness is counterbalanced by the fact that the same quantity of palladium can be used for an indefinite time. If heavily charged with hydrogen, it is only necessary to shut off by suitably arranged cocks the communication between the pipe filled with palladium and the rest of the plant and to lead atmospheric air through this pipe, whereby the palladium-black or gauze loses all hydrogen absorbed and is ready for use again. As one volume of palladium absorbs 800 volumes of hydrogen I do not think that even for a large plant more than one-half pound of palladium is required, as in the immensely finely distributed form in which it is used a small mass obtains an immensely large surface.

Now, let us see how much the cost caused by this purification process is. Let us make this calculation for an ammonia which, manufactured in the usual way, has the following composition, viz:

	Per Cent.
Ammonia,	98·976
Moisture,	0·040
Colorless fluid,	0·950
Hartshorn salt of ammonia,	0·030
Lubricant oil,	0·004
Mineral matter,	traces

Having above stated that one pound of colorless fluid requires 0·38 pound of metallic sodium, 0·36 pound of it is here required. One pound of metallic sodium costing $1.20, the quantity required costs forty-three cents. The metallic sodium required for the removal of each one hundredth of one per cent. of moisture costing 1·6 cents and that for the removal of each one hundredth of one per cent. of hartshorn salt costing 0·7 cents, the total expense for metallic sodium is fifty-two cents per 100 pounds of liquid ammonia. But 100 pounds of the ammonia in question yielding only 98·976 pounds of chemically pure ammonia, there is a loss of 1·024 per cent. The price of one pound of liquid ammonia being about thirty-five cents, this loss is equal to thirty-six cents. Or, the total increase of the manufacturing cost for 100 pounds is eighty-eight cents. But for this slight increase of cost we obtain a liquid ammonia which contains 99·996 per cent. of ammonia instead of the 98·976 per cent. as at present, and therefore will easily command a much higher market price.

In this calculation the sodium alcoholates resulting by the action of the metallic sodium on the colorless fluid are considered to be without any commercial value. But this is not so. By addition of water to the sodium alcoholates, and distilling with return steam the whole quantity of alcohols which was present in the raw material can be regained, and by introducing its market value into the calculation, the above stated increase of manufacturing cost will be considerably lessened.

While thus by my new process at a slight increase of cost liquid ammonia of 99·995 per cent. is obtained, the refrigerating power of which, is, of course, superior to that of the present commercial liquid ammonia, and thus the liquid ammonia sold as "strictly chemically pure anhydrous 100 per cent." really is what it is represented to be, there is still another point worthy of consideration. Every one connected with the refrigerating business knows of the terrific explosions which now and then occur in refrigerating plants, and for which heretofore no plausible cause could be given. While I cannot positively say how these explo-

sions originate, I should think that the presence of such inflammable bodies as alcohols and ketones point to where the cause for those explosions may be looked for. It is not at all necessary, or not even likely, that the alcohols, etc., in their present form cause the explosions, but after being decomposed into hydrocarbons, etc., the latter may do so. As answer to the question of how under the conditions given in a refrigerating plant, such a decomposition can take place, I would say that this can be done by the thermo-electricity developed by the ammonia condenser. The iron return bends being tightened to the iron pipes of such a condenser by means of tin solder; and, because of the current of the ammonia gas or liquid ammonia respectively through the condenser, the tin solderings on one side of the iron pipes being colder than the tin solderings on the other side of said pipes, and the end of the condenser where the liquid ammonia leaves the same, being connected by pipes with the end where the ammonia gas enters the same, all the conditions necessary for the development of thermo-electricity are given. The electro-motive force thus developed is, of course, only very small, but in the course of time enough hydrocarbons, etc., may be generated, which after being brought to explosion, may shatter the strongest iron pipe.

I intend to try to find out by experiment whether or not this supposition of mine be correct.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, May 31, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-two members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and lantern slides, which were approved and ordered paid.

The Committee on Admissions reported one election to membership since last meeting.

Mr. E. G. Willyoung described a series of experiments to determine the disturbing magnetic effect of so-called non-magnetic substances in sensitive measuring instruments. Out of a large list of substances experimented with, glass and paraffine were the only entirely non-magnetic ones.

Prof. Edwin J. Houston read a paper describing two methods of obtaining "A Graphic Representation of the Magnetic Field," illustrated by photographic prints and lantern slides. Referred for publication. In discussion thereon, Prof. Rondinella described two other methods that he had used for obtaining similar permanent records.

Mr. Carl Hering stated that he thought the iron filings method misleading, as in the strongest parts of the field the filings were often bunched in one spot, leaving another adjacent to it entirely bare. He preferred the method of investigating a magnetic field by means of a small freely-suspended magnet.

Prof. Edwin J. Houston read a paper on "The Physiological Effects of Alternating Currents of High Frequency." Referred for publication.

Mr. C. W. Pike described "The Disturbing Effects of External Magnetization upon the Weston Measuring Instruments." Referred for publication.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

EFFECT OF EXTERNAL MAGNETIC DISTURBANCES ON WESTON INSTRUMENTS.

CLAYTON W. PIKE,
Dept. Mechanical and Electrical Engineering, University of Pennsylvania.

[*Read at the meeting of Electrical Section, held May 31, 1892.*]

The Weston instruments are slight modifications of the well-known D'Arsonval galvanometer. In the voltmeter we have a pivoted fine wire coil turning between two poles of a permanent magnet, the restoring force being a pair of watch springs.

The action is as follows: When the terminals of the coil are connected to the points whose potential difference we wish to measure, a current flows through the coil proportional to this P.D. This current sets up lines of force and these acting upon the lines due to the permanent magnet cause a force which deflects the needle. It is evident that anything which permanently or temporarily changes the number of lines of force passing through the coil due to the permanent magnet will make the reading different from what it should be for a given P.D. at the terminals of the coil.

Owing to the difficulty of maintaining constant the strength of a powerful magnet, Mr. Weston employs a comparatively weak one, and hence we should naturally expect that comparatively small magnetic disturbances would affect the instrument.

In fact, the earth field exerts an appreciable influence and this fact is taken account of in the calibration of the instruments, although for commercial work the effect is too small to be of any account.

The effects to which I desire to call attention are those of the commercial or workshop order.

In many tests such as determination of the characteristic curve of a machine, the resistance of armature or fields, coëfficient of magnetic leakage, etc., two instruments are employed and the question comes up, how far apart must we put the two instruments so as not to affect each other appreciably.

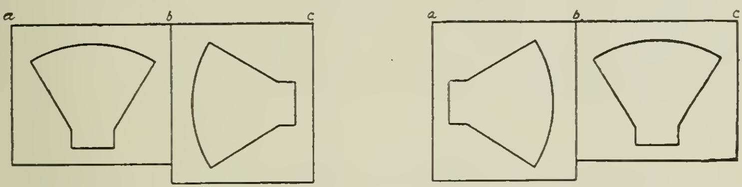
One of my students, Mr. J. A. Stewart, has made at my suggestion some quite extended experiments upon this point and finds that:

(1) A Weston instrument placed close to another may change its reading by about five per cent. The matter is then worth investigating.

(2) That as far as its disturbing influence goes, it makes practically no difference whether the disturbing instrument has current through its coils or not.

(3) That two instruments placed a foot apart from each other in any position do not affect each other's readings by one-fourth per cent.

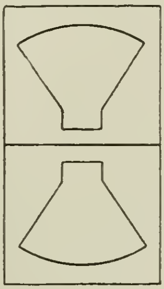
It is often convenient, however, if one person is reading both instruments, to have them as close as possible, and Mr. Stewart showed that the best position was either of these two.



It is best that the points *a b c* should be in the same straight line.

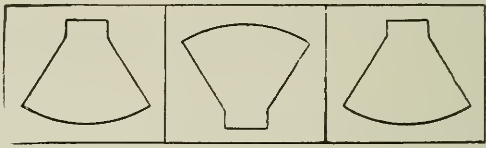
When this is the case neither instrument affects the reading of the other by as much as one-fourth per cent.

The maximum disturbance of five per cent. was reached as would be expected in this position.



We next wanted to find what effect would be produced by some things liable to occur in a workshop.

An ordinary twelve-inch file was placed in different position near a Weston instrument while measuring about half the amount possible. The file, when every part of it was at least four inches distant, produced practically no effect, but when placed thus, changed the deflection over four per

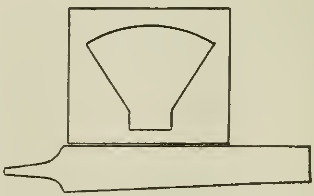


cent. An ordinary bench vise also acted just like the file, having no effect at four inches, but introducing an error of four per cent. when placed in position where it had its maximum effect.

The reason for this action is clear. Take the case of the file above. It evidently leads away from the coil a part of the lines of force due to the permanent magnet. There is then not so strong a deflecting force, and the reading is too small.

As to the effect of very powerful magnets, as those of a dynamo, we have not made sufficient experiments for publication.

Once in a while it is convenient to place three instruments together, and this arrangement gives an error of less than one-half per cent.



The observance, then, of very slight precautions, will allow us to place our instruments in any desired proximity without vitiating, to any appreciable extent, our results.

AMPÈRE-CENTIMETRE, A MEASURE OF ELECTRO-MAGNETISM.

BY CARL HERING.

[*Read at the meeting of the Electrical Section held May 3, 1892.*]

It appears from the following deductions that an electric current multiplied by the length of the circuit will represent the number of magnetic lines of force generated by this current, or, in other words, that the number of lines of force generated by a current can be measured by the product of the current and the length of its circuit. A unit current passing through a unit length of circuit, appears to generate a certain fixed and constant number of lines of force. This, of course, has reference to the electro-magnetism of the current itself and does not include the influence of any magnetic bodies in the neighborhood.

First of all it is necessary to show that ampères multiplied by length will give a unit of a similar nature to magnetic lines of force or flux, in order to show that an equivalent between the two may be given without transgressing the laws of physics. This may be shown conclusively by the aid of the dimensions of these units in the absolute system. The dimension of current is $m^{\frac{1}{2}}\, l^{\frac{1}{2}}\, t^{-1}$, while that of magnetic flux (that is, number of lines of force, not their density per square centimetre usually represented by H or B, nor the intensity as it is sometimes called), is $m^{\frac{1}{2}}\, l^{\frac{3}{2}}\, t^{-1}$. It will be seen that the former multiplied by a *length* gives the latter. This shows conclusively that ampère-centimetres, or ampère-feet and magnetic flux are units of the same kind and can therefore be equalled.

Having determined this point, the following appears to show that every unit length of a circuit conveying one ampère, generates a fixed and constant number of lines of force. Using absolute units, the intensity of magnetization (or number of lines per square centimetre) at the centre of

a circle of one turn, according to the well-known formula, is

$$H = \frac{2c\pi}{r}$$

in which r is the radius in centimetres and c is the current.

Now, the intensity of the field is different in different parts of the area enclosed by the circle, being greatest nearest to the wire, but it may be assumed that in all circles, large or small, the ratio of the intensity at the centre, to the average intensity in the whole circle, is a constant. Let this ratio be called K, then the total number of lines will be equal to the intensity at the centre multiplied by the area, and by K; that is,

$$M = \frac{2c\pi}{r} \times \pi r^2 \times K = 2c\pi^2 rK$$

By dividing this by the circumference will give the number of lines per unit length of the circuit

$$2c\pi^2 r K \div 2\pi r = C\pi K$$

or per unit of current, this is equal to πK. It will be seen that this is a constant and is *independent of the radius r*. This means that the number of lines per unit length and per unit current is the same for all circles, and therefore also for a straight line, which is a circle of infinite radius.

From this it appears that, knowing this constant number of lines per ampère per centimetre or foot, the calculation of the total number of lines generated by any circuit or coil, would merely be the product of the current, the length of the circuit, and a constant.

It should be remembered, however, that this deduction supposes theoretical conditions; that is, a filamentary wire having no appreciable diameter. How far the size of the wire introduces an error remains to be determined. At all events, if the diameter of the wire is small as compared with the diameter of the coil, and specially if the coil, as it usually does in practice, contains iron which appears to concentrate the lines in it, and therefore probably attracts those circulating in the body of the wire itself, it may doubtless be assumed that the ratio of the flux in two coils

would be equal to the ratio of their ampère-feet, which proportion might be of use in dynamo construction.

The above deductions were made by the writer a number of years ago, but as they did not appear to agree with some existing laws at that time, the matter was laid aside. It seems, however, that subsequently some dynamo builders have advocated and used this system of calculation in preference to the other, and it was therefore thought best to publish this proof, hoping that some others, well informed on this subject, might point out the discrepancies if any, and perhaps show the extent of the application in practice of calculating the magnetic flux of a current from the ampère-centimetres of the circuit.

The PHYSIOLOGICAL EFFECTS of ALTERNATING CURRENTS of HIGH FREQUENCY.

By Prof. Edwin J. Houston.

[*Read before the Electrical Section of the Franklin Institute, May 24, 1892.*]

Gentlemen:—I have concluded to place on record a brief statement of the substance of some remarks made by me at the last meeting of the section, concerning the physiological effects, on the human body, of alternating currents of very high frequencies.

As is well known, the physiological effects of alternating discharges of but moderate frequencies are more severe than are those of steady currents of the same current strength. As, however, the rapidity of alternation increases, the severity of the physiological effects decreases, until, at extraordinarily high frequencies, all harmful physiological effects practically disappear.

Three varieties of electric discharges or currents are employed in electrotherapy for the treatment of diseased conditions of the body.

(1) The steady, continuous currents produced by voltaic batteries, and called, in electrotherapeutics, Galvanic currents.

(2) The alternating currents produced by induction coils and called, in electrotherapeutics, Faradic currents.

(3) The electrostatic discharges obtained from frictional or influence machines and called, in electrotherapeutics, Franklinic currents.

As is well known, the physiological effects produced by Galvanic currents differ markedly from those produced by Faradic currents. The former, unless very powerful, produce on the opening or closing of the circuit, a contraction that is of very short duration—in fact almost but momentary; the latter produce a contraction that continues as long as the current is passing. This is generally believed to be due to the fact, that the contractions attending the opening and closing of the circuit, follow one another so rapidly that the muscles fail to assume the condition of rest and so present the appearance of continuous contraction.

Franklinic currents produce, in general, effects somewhat similar to those of Faradic currents.

When alternating currents are sent through the human body the physiological effects increase in severity with an increase in the current strength. With current strengths greatly in excess of those employed in electrotherapy additional effects are produced, and a tonic contraction of the muscles follow. Moreover, in such cases the severity of the physiological effects is increased by the high potential of the break-induced discharge.

As, however, the rapidity of alternation increases, the severity of the physiological effects decreases until, when enormously high frequencies are reached, the discharges become harmless. These facts have been demonstrated by Dr. Tatum for comparatively high frequencies, and by Nikola Tesla for enormously high frequencies.

In a lecture delivered before the American Institute of Electrical Engineers, at Columbia College, New York, on May 20, 1891, Tesla, speaking of these effects, says:

"I have found that by using the ordinary low frequencies, the physiological effects of the current required to maintain, at a certain degree of brightness, a tube four feet long, provided at the ends with outside and inside condenser

coatings, is so powerful that I think it might produce serious injury to those not accustomed to such shocks; whereas, with 20,000 alternations per second, the tube may be maintained at the same degree of brightness without any effect being felt.

"This is due principally to the fact that a much smaller potential is required to produce the same light effect and also to the higher efficiency in the light production. It is evident that the efficiency in such cases is the greater the higher the frequency, for the quicker the process of charging and discharging the molecules, the less energy will be lost in the form of dark radiation."

The severity of the physiological effects attending any electric discharge through the body must necessarily depend to a considerable extent not only on the quantity of energy present in the discharge, but also on the time in which it is acting.

It has occurred to me that in another circumstance is to be found, perhaps, the principal cause why discharges of enormously high frequency of alternation should be so comparatively harmless. This fact, I think, is to be found in the manner in which, according to our modern ideas, an electric discharge is believed to pass through a conducting path or circuit, viz: that the electric energy is not propagated through the mass of the conductor itself, but rather through the dielectric or other medium lying outside the conductor. That the electric energy is rained down on the surface of the conductor from the space outside it, and sinks down into the mass of the conductor, the conductor forming a sink or place where the energy can be dissipated.

In the case of a steady, continuous current, the energy sinks or soaks rapidly through the mass of the conductor, so that the electric current, in the language of the old ideas, passes through all portions of the mass of the conductor.

In the case of alternating currents, however, the energy received from a single impulse or electrical movement, by sinking or soaking moves (say) from the surface of the conductor towards the centre, only while such impulse con-

tinues; and, when the direction of the impulse changes, moves in the opposite direction, or towards the surface. In conductors through which alternating currents are passing, the current density is therefore greatest near the surface portions, and, in the case of alternations of very high frequency, the central portions of the conductor are entirely free from electric currents, the current being limited to portions near the surface.

In the case of the enormously high frequencies employed by Tesla, this action was so pronounced that conductors failed completely to conduct.

When, therefore, the human body is subjected to the effects of discharges of alternating currents of enormously high frequencies, the superficial portions only are traversed by the discharges. The more deeply seated, vital organs, being thus free from current, such discharges are necessarily harmless.

As the frequency of alternation increases, the body becomes more and more protected, until, when the frequency becomes as great as that of the ether waves, which cause sunlight, they would probably produce on the surface of the body the same genial effects as are produced by the light and heat of the sun, with which they are probably identical.

If these views are correct, it would appear that when the human body is exposed to rapidly-alternating discharges, it is subjected at one moment to a discharge that might produce instant death, were it not for the fact that the bolt is practically no sooner hurled at the body than it is hurled away from it.

A GRAPHIC REPRESENTATION OF THE MAGNETIC FIELD.

BY PROF. EDWIN J. HOUSTON.

[*Read before the Electrical Section of the Franklin Institute, May 31, 1892.*]

Being engaged in a study of the magnetic field and desiring to obtain some simple method of fixing and readily reproducing the peculiarities of different fields, I have, after numerous trials, succeeded in devising a modification of an old and well-known plan, so simple and efficient, that I have thought it may be of sufficient interest to others engaged in similar investigations, to describe it in detail.

The method consists essentially in forming a magnetic field with iron filings on a plate of glass in the usual manner, and subsequently fixing the filings so as permit the plate to be used as a positive for obtaining a blue print, a silver print, a platinotype, or any other photographic print.

In order to readily fix the groupings of filings on the glass plate while in the field of the magnet, a thin film of wax is spread over one surface of the plate by any suitable process.

A convenient method of waxing the surface of the plate consists in first gradually heating the plate until its temperature is above that of the melting point of wax, and spreading melted wax over its surface by means of a brush. The surplus wax is then allowed to drain off the plate, or it may be wiped off by a piece of warmed paper. The remaining wax is then spread in an even film over the surface by cautiously heating the plate by a Bunsen flame or other suitable source of heat; or, the same thing can be effected by placing the plate in a vertical position in an oven or sand bath, supported on a suitable vessel so as to catch the surplus wax which drains off.

Plates can be readily covered in this manner with an uniformly thin coating of wax sufficiently transparent to permit them to be successfully employed for photographic

printing. For such purposes of course, only pure, white wax is employed.

The wax-covered glass plate so prepared is placed with its waxed surface upwards, in a horizontal position over the

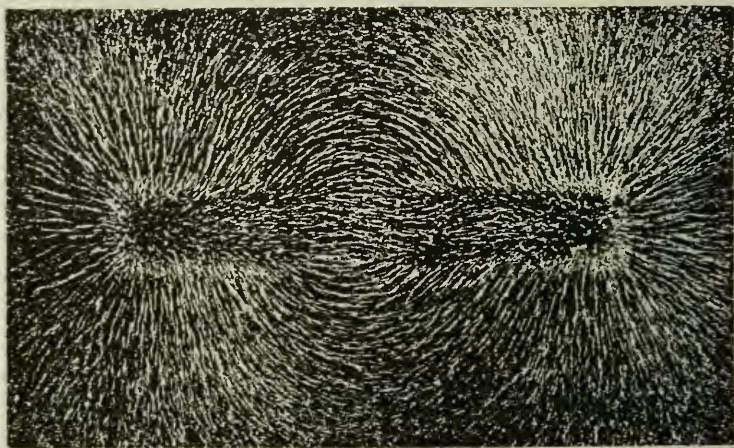


FIG. 1.—Field of bar magnets.

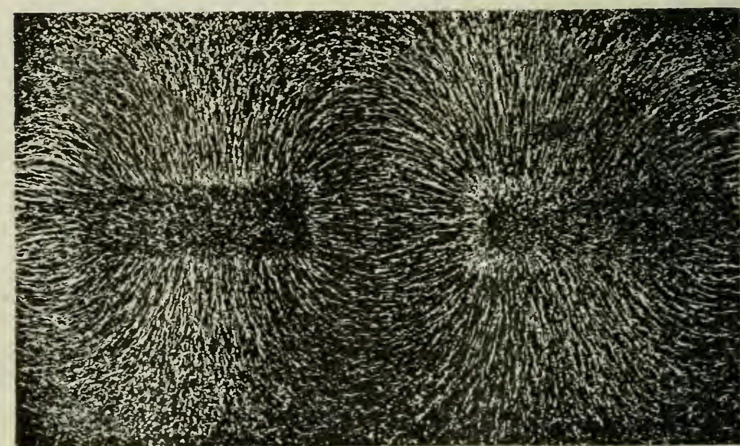


FIG. 2.—Opposite poles of bar magnets.

magnet whose field is to be fixed, and iron filings are sprinkled over its surface. The arrangement of the filings in the characteristic groupings of the field, is aided by gently tapping the plate in the usual manner.

When a satisfactory grouping of filings has been obtained, the field is fixed on the plate by gently warming it so as to melt the wax. At first I adopted the plan of carefully lifting the plate from the magnet and melting the wax by holding it over a source of heat, such as a Bunsen burner; but, no matter how carefully the plate was lifted from the magnet, or how nearly it was raised vertically from the same, so as to avoid lateral displacement of the filings, a change of figure almost invariably attended its removal. Better results were obtained when the wax was melted while the plate was in place over the magnet. This can readily be

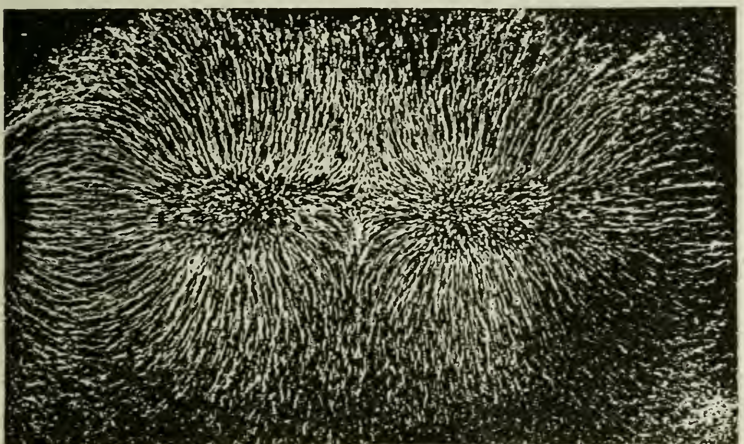


FIG. 3.—Similar poles of bar magnets.

effected either by holding a heated plate over the warm surface, or more conveniently by cautiously heating it by a Bunsen flame. After a slight heating, the flame may be permitted to play directly on the surface of the filings without displacing them.

After cooling, the plate with its fixed groupings of iron filings may be used as a positive for photographic printing. For this purpose it is placed in a printing frame with its surface of wax-fastened groupings of filings upwards, so as to come into contact with the surface of the sensitized paper.

If the plate has been properly prepared, but comparatively few filings will become detached from the waxed sur

face when it is brought into contact with the sensitized paper. These should be blown off before taking a second print from the plate.

In order to obtain the minimum of roughness of surface,

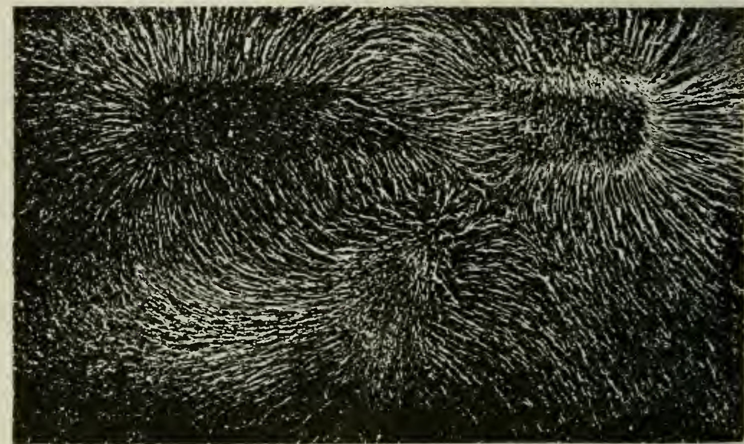


FIG. 4.—Bar magnets at right angles to each other.

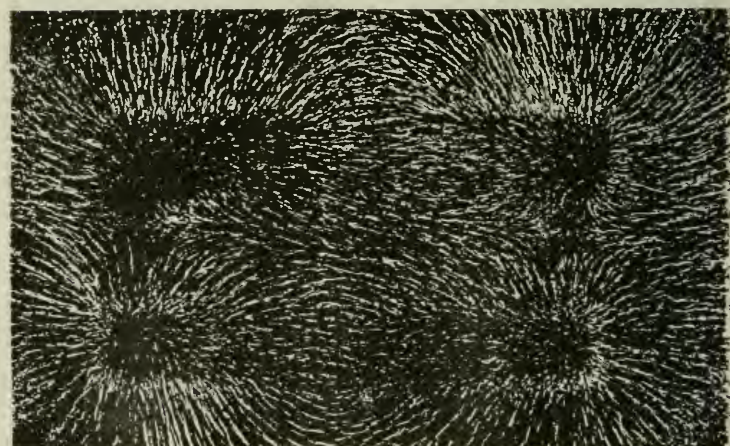


FIG. 5.—Parallel bar magnet. Similar poles opposed.

it is necessary to use filings that are as nearly as possible of a uniform size. This can be readily ensured by previously sieving them through a fine meshed wire gauze.

It is advisable that the plates be covered with as smooth a coating of wax as possible. Otherwise, the filings will be

prevented from readily arranging themselves in the directions which the lines of magnetic force pass.

In the case of powerful electro-magnets care must be taken to avoid a too great motion of the filings to the poles, since, in this manner, the portions of the surface over which the particles are moved, are swept clean of filings.

The best results are obtained by sieving the filings over the plate through a sieve whose meshes are sufficiently fine to ensure a small quantity only of filings falling on the plate at any one time. This, of course, is necessary to ensure the uniform distribution of the filings in the field of the magnet.

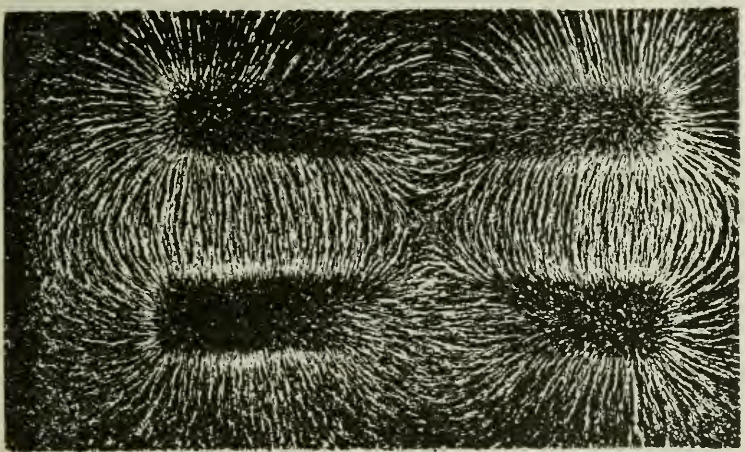


FIG. 6.—Bar magnets. Dissimilar poles opposed.

When the plates on which the magnetic fields are so fixed, are used for positives for photographic reproduction, and negative prints obtained therefrom in black, as by means of a silver print, or a platinotype, such prints can readily be used for the purposes of graphic reproduction for printing by any of the well-known photographic processes. In this way cuts and illustrations of actual fields can be readily had for purposes of illustration, without the introduction of those well-known errors arising from the too great artistic imagination of the copyist.

For purposes of subsequent reproduction I find platino-

type paper the best, as it gives dead blacks, that contrasting markedly with the white lines and spaces occupied by the iron fillings are readily photographed by any of the well-known processes of reproduction.

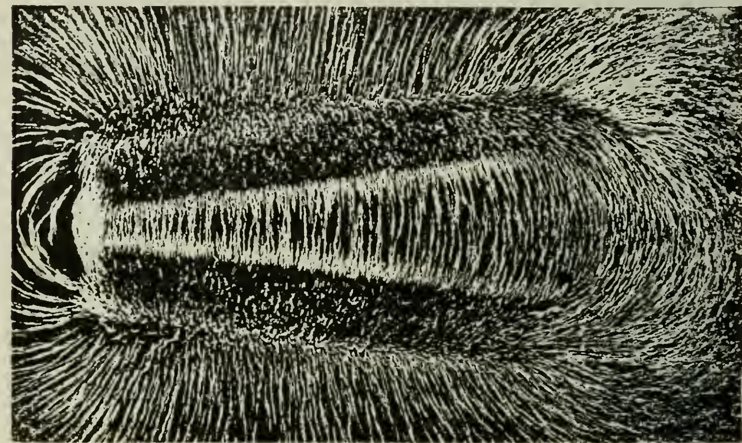


FIG. 7.—Field of horseshoe magnet.

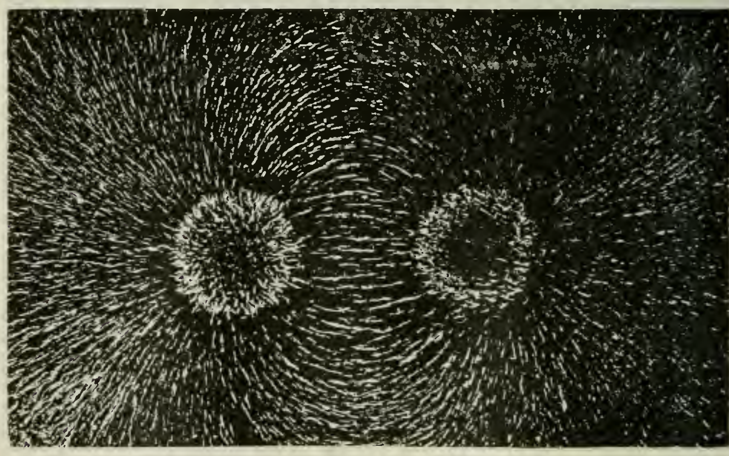


FIG. 8.—Field of electro-magnet.

When the filings are dusted over the plate from a sieve held a few feet above the waxed surface rather than quite near its surface, a better grouping of the filings is obtained.

I have prepared a number of fields according to the pro-

cesses described. They have been printed by the platinotype process.

In *Fig. 1*, is shown the field of a straight bar magnet. The characteristic radiation of the lines of force at the poles is well shown, as well as the curved lines produced by the mutual attraction of the lines coming out of the north and proceeding towards the south pole. The numerous parallel lines at the equator of the magnet show the strength of the magnetic flux at that point.

Fig. 2, shows the field produced by the approached, unlike poles of two straight bar magnets. The attraction of the

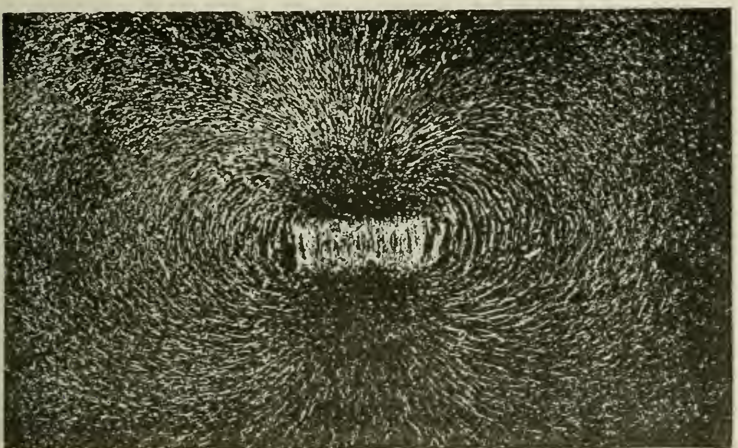


FIG. 9.—Field of permanent horseshoe magnet.

oppositely directed lines of force in the space between the opposing poles, as well as the increase in the length of space on the bars from which the lines pass off approximately at right angles to the surface, are well marked.

Fig. 3, shows the field produced by the approached, similar poles of the same straight bar magnets used in *Fig. 2*. The repulsion of the similarly directed lines of force producing nearly straight paths in lines at right angles to the length of the magnet, as well as a curious space midway between the poles, bounded by apparently hyperbolic curves are clearly seen.

Fig. 4, shows a very curious field produced by two bar magnets placed with their axes at right angles to each other so that one of the poles of one magnet is placed at right angles to the neutral point of the other and at a short distance from it. At the left-hand of the field is shown the curved deflections of the lines of force produced by the attractions of opposite poles. The lines of force coming out of a north pole and those entering at a south pole mutually attract one another and produce curves similar to those shown in the space between the approached, opposite poles shown in *Fig. 2*. At the right-hand of the field the repul-

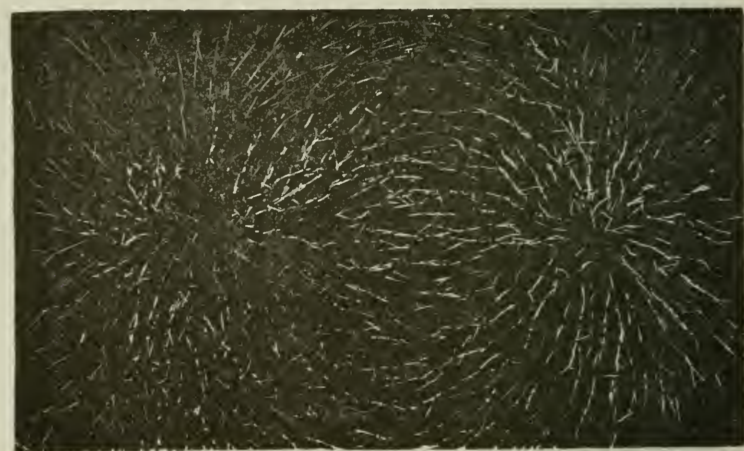


Fig. 10.—Wire field of bar magnet.

sions existing between the similarly directed lines of force produce characteristic parallel streamings. The curious area bounded by hyperbolic curves is shown in the space between the poles at the right of the figure.

Fig. 5, shows the field produced by two straight bar magnets placed with their axes parallel to each other and their similar poles near together. The mutual repulsions of their fields are clearly shown. The curious areas bounded by hyperbolic curves are shown in the spaces at each end between the poles of the magnets.

Fig. 6, shows the field produced by the same parallel bar magnets placed with their opposite poles near together.

The attraction of their oppositely directed lines of force is well marked. In the neighborhood of their neutral points, a very marked area bounded by hyperbolic curves is seen. The strength of the magnetic flux near the neutral points is also marked.

Fig. 7, shows the field of an ordinary horseshoe magnet. The magnetic leakage between the sides of the bar is marked, as is also the strength of the magnetic flux in the neighborhood of the equator or neutral point of the magnet.

Fig. 8, shows the field of an electro-magnet. In order to

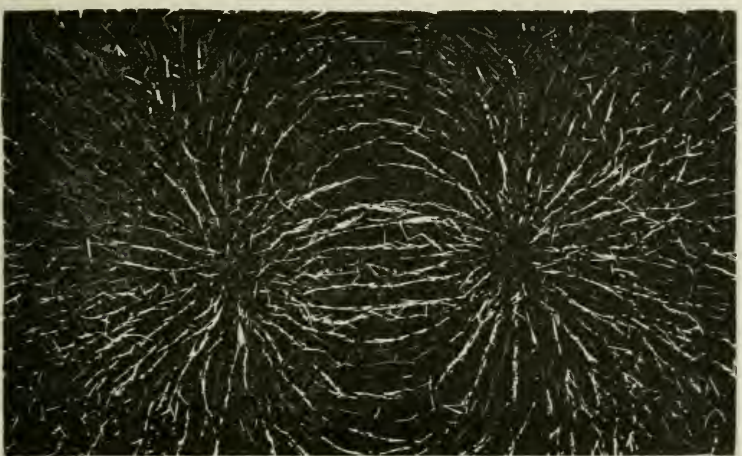


FIG. 11.—Wire field of electro-magnet.

avoid the injurious sweeping action of the particles as they are carried bodily forward towards the poles, I found it necessary to use a very weak current, and to place the plate a short distance above the poles.

It may be mentioned in this connection that it is in general advisable to avoid resting the plate on the surface of the magnet, since when the plate does not touch the poles it is left free to be gently tapped or vibrated so as to permit the filings to arrange or group themselves while in the field of magnet.

Fig. 9, shows the field of a peculiarly shaped permanent

horseshoe magnet taken in a plane over the poles at right angles to the length of the magnet. I was rather surprised in this case to find that so many of the lines of force passed through extended air circuits shown rather than through the narrow gap directly between the poles.

Fig. 10, shows a novel field obtained by short lengths of very thin iron wire, that act as small magnetic needles. The field is that of the bar magnet employed in *Fig. 1*. Although the separate particles do not possess as great freedom of motion as the shorter and smaller iron filings, yet their tendency to come to rest with the lines of magnetic

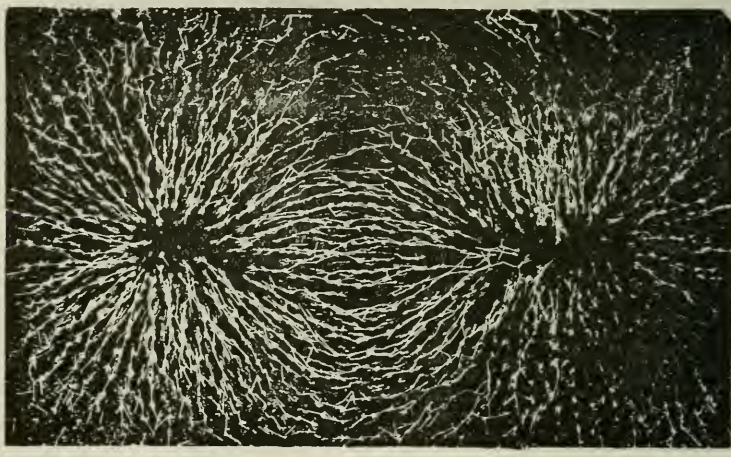


FIG. 12.—Wire and filings field.

force passing through their greatest dimensions, so as to reduce the resistance of the magnetic circuit as much as possible, is manifest.

The peculiar wire field produced by these means is of especial interest when studied in the light of Ewing's theory of magnetism.

Fig. 11, shows another wire field produced by the same electro-magnet as is employed in *Fig. 8*. The polarization of the minute magnetic needles and their arrangement in groupings of polarized chains is well marked.

Fig. 12, shows a field produced by iron filings and iron

wire. The peculiar groupings of the iron wire in chains of polarized particles are clearly shown.

A curious resemblance is possessed by this field and other wire fields to the discharge produced by a lightning flash, or other high potential discharge; such, for example, as the recent 500,000 volt discharge of Elihu Thomson. This resemblance quite naturally leads to the speculation, whether the peculiar forked or curved shapes of such discharges are not due to similar causes, viz: to polarized chains of particles of the medium which offers paths of less resistance to the discharge than the spaces adjoining or surrounding them.

I am making some experiments in solid fields, *i. e.*, in the peculiarities of the distribution of the lines of force in the space of three dimensions surrounding magnets, which I trust to be able shortly to bring before you.

I desire to express my indebtedness to my assistant, Mr. B. F. Lacy, for valuable aid in preparing the plates.

Since writing the above my attention has been called to the fact that the process above described has been very fully anticipated by Prof. Mayer, in a publication printed in the *Journal of the Franklin Institute*, for May, 1871. As my process differs in some particulars from that described by Prof. Mayer, and as it appears to me advisable to call attention to both processes at this time, I have concluded to permit the paper to go to publication. To Prof. Mayer, however, the credit is due for the first conception of the general process.

Since writing the above on last Saturday, I have devised a new plan which I believe to be far in advance of what I have just described.

According to this plan I place a dry sensitized photographic plate over the magnet whose field I desire to fix and after the characteristic groupings of filings have been obtained, I expose such plate while over the magnet to the light of a gas flame for a few seconds.

This operation is necessarily performed in the dark photographic room. After exposure the light is turned out and only the non-actinic red or yellow light left. The filings are allowed to fall off the surface of the dry plate, and the

finer particles that still adhere to it are brushed off by a feather or dry camel's hair brush. The plate is then developed and fixed in the usual manner.

The removal of the adherent iron dust by the feather or brush is preferable to the use of the breath, as this is apt to produce troublesome spots.

I have found that the so-called lightning gelatine dry plates give very satisfactory results when employed for such purposes.

This process of obtaining records of magnetic fields produces true negatives, which when employed for printing by blue print, silver print, platinotype, or similar process produce excellent positives.

As the negatives so obtained are more permanent than the positives obtained by the use of the filings themselves, they permit the taking of an indefinite number of photographic prints.

I have thought of forming the field directly on the surface of sensitized paper and exposing such to light. But such paper is apt to curl, and such processes produce but a single impression.

The time has been too short to prepare many specimens of fields by this new process. I hope to be able, however, by the next meeting of the section, to present such results in a short paper.

BOOK NOTICES.

Appleton's School Physics, embracing the results of the most recent researches in the several departments of natural philosophy. By Profs. Quackenboss, Mayer, Nipher, Holman and Crocker. New York, Cincinnati, Chicago: American Book Company. (From the press of D. Appleton & Co. N. D.) Price, $1.20.

A work prepared by a half-dozen different hands might be expected naturally to exhibit some unevenness on this account. The present volume, however, so far as we have had the opportunity of examining it, appears to be in all respects admirably prepared and well adapted for its intended purpose of serving as an elementary text book. In its treatment of first principles, it is fully abreast with the most advanced conceptions of the leaders of modern thought and the method of presenting abstruse subjects is characterized by a clearness that is as satisfying as it is rare in works of its class. W.

The Ventilation of Buildings. By Alfred R. Wolff, M. E., Member Am. Soc. Mech. Engrs., etc. (Second Edition.) New York: Author, Potter Bldg. N. D. Price, 25 cents.

The extended notice of this excellent paper, which appeared in the *Journal* about a year ago, renders it unnecessary for us to do more than call attention to the appearance of a second edition. There is no better general treatment of the subject in the language within such compact limits as these 32 octavo pages, and if the author could be persuaded to elaborate the paper, so as to discuss at length the special systems used and with suitable illustrations, its usefulness would be greatly increased, without sacrifice of its technical merits. W.

Les Theories Modernes de l'Électricité. Essai d'une theorie nouvelle. Par O. Lodge. F.R.S., etc. Traduit de l'Anglais et annoté par E. Meylan, ingénieur civil, etc. II vols. 8vo, with figures in the text. Paris: Gauthier-Villars et Fils. 1891. (Price, 5 francs.)

This translation of the work of Lodge, so well known to English-reading students of electricity, appears to be the first attempt to place before French readers, in their own language, the modern conception of electricity and magnetism, as in some direct manner an affection of the lummiferous ether, which is entertained and advocated by Maxwell, Sir Wm. Thomson and other leaders of scientific thought. The translator has performed his task with fidelity and his intelligent annotations of the original text add notably to the value of the translation. W.

Report of Committee on Disposal of Waste and Garbage, presented at the Nineteenth Annual Meeting of the American Public Health Association, Kansas City, October 20–23, 1891. Concord, N. H.: Republican Press Association. 1892.

This report will be found specially valuable to city engineers, municipal authorities and sanitary engineers. It contains, among other valuable information, a *résumé* of the practice of a large number of American cities in relation to the disposal of waste and garbage, an excellent paper giving valuable hints on this important subject, and some interesting data embodying foreign experience in solving the problem. W.

Modern Practice of the Electric Telegraph. A technical hand-book for electricians, managers and operators, with 185 illustrations. By Franklin Leonard Pope. (Fourteenth edition, rewritten and enlarged.) New York: D. Van Nostrand Company. London: Sampson, Low, Marston & Co. 1891.

The author has appreciated the fact that the unparalleled progress within the past ten years in all that pertains to the application of electricity to the industrial arts, has also materially affected the theory and practice of the electric telegraph. He has recognized the fact by preparing, not a new edition of his standard work, but, substantially, a new book, in which the principles and practice of the electric telegraph from the modern standpoint are most thoroughly explained and illustrated. W.

The Separate System of Sewerage. By Cady Staley and Geo. S. Pierson. (Second edition.) New York : D. Van Nostrand Company. 1891.

The first edition of this work was reviewed in our issue of September, 1887, and we can only add to the favorable comments then made, by saying that the present edition contains nearly 100 additional pages, the perplexing and important question of sewage disposal being treated in a manner which increases the value of the work. W. B. C.

ERRATUM.

Book Notices, June, 1892, on line 7, p. 503, for "decreased" *read* "increased."

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 15, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 15, 1892.

JOS. M. WILSON, President, in the chair.

Present, 128 members and eight visitors.

Additions to membership since last report, seven,

The actuary submitted a resolution of the Board of Managers referring to the Institute a communication from Mr. Alex. De Beaumont, in which he requested to be accorded the privilege of being reinstated as a member. The Secretary thereupon presented Mr. De Beaumont's communication, and on motion of Mr. H. R. Heyl, it was resolved, in view of the statements contained in the said communication that Mr. De Beaumont be accorded the privilege of reinstating himself as a member of the Franklin Institute.

Mr. Pedro G. Salom read a paper on the "Present Status of the Storage Battery System of Electric Street Railway Propulsion." (Referred for publication.)

A paper of Dr. Wellington Adams, entitled "From Chicago to St. Louis by Electric Express," which was announced for the evening, was deferred on account of a despatch from Dr. Adams, announcing his unavoidable absence.

Mr. S. Lloyd Wiegand described and illustrated certain improvements in the manufacture of artificial limbs, devised by the brothers Marks, of New York, which involved the application of aluminum. On motion of Mr. W. M. McAllister, the subject was referred to the Committee on Science and the Arts.

The Secretary presented a brief report, and Mr. W. N. Jennings made an exhibition of a number of photographic pictures of local interest.

Adjourned. WM. H. WAHL, *Secretary.*

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A MOTOR WITHOUT FUEL AND THE SECOND PRINCIPLE OF THERMO-DYNAMICS.

BY DR. HERMANN MEHNER.

[*Read at the stated meeting of the Institute, December 16, 1891.*]

JOS. M. WILSON, President, in the chair.

DR. MEHNER: Since the time when men began to use motors, thinking and progressive minds have been impressed by the value of the precious service done by mechanical power, and have been seeking to produce such mechanical power. The histories of the investigators in this field are sad—hard toil, bitter deceptions, meagre successes. Wherever nature showed, or seemed to show, an unutilized force, these eager explorers in mechanical powers exerted their best endeavors, and they were deceived, either because there was no force or because the force was not able to do work or required mechanical work to make it available.

Of such was the constructor of the *perpetuum mobile*, who, in his imagination, ran a wheel around inside of a hoop by the continuous force of a coiled piece of watch-spring—the philosophical miller who proposed to pump his water back and use it over and over again in his wheel.

These inventors were deceived by natural causes, but others have found their work to be useless because of social conditions. Such was the case with the unhappy genius Papin, who knew a peculiar force, which we call the pressure of the atmosphere; who knew how to produce conditions under which this force was able to do work and thus had in his vessel a wonderful energy capable of moving for a distance of several feet the respectable weight of fifteen pounds for each square inch, and to repeat this as often as he pleased, but he could not sell it.

Social conditions prevented him from developing his device, even to the low level of the Newcomen machine.

We pity Papin, but, to my way of thinking, we owe as much sympathy to the deceived inventor with the watch-spring and the unfortunate miller, the strong-minded men who work hard, much less for their personal interest than with the magnanimous desire to confer a gift valuable to mankind.

For it is much simpler and easier to grind grain and make money, and afterwards to celebrate thanksgiving, than to grind thoughts against thoughts, make sacrifices of pleasure, time and money, and to keep at this after many meagre and bitter thanksgivings.

Mankind owes its thanks to these deceived inventors because especially in the early state of mechanical science the record and the discussion of such unsuccessful explorations increase the chances of those who at length achieve success. As there is no plan, guide or time-table for travellers in the darkest Africa of natural philosophy, there is nothing for the pioneer but to try.

The search for power where there is none, advanced scientific mechanics just as alchemy advanced early chemistry.

If the search for sources of mechanical power brings one

success, the advantage to the commonwealth pays a thousandfold all the loss which futile experiments have inflicted upon it. Watt's fortunate contrivance is not a mere object of property; it is the *foundation* of our present form of commonwealth, technically and socially.

Nowadays steam-power is all: but for the inventor it is nothing.

The very abundance of mechanical power and its application for so many purposes, show how this application is limited and impress the mind that another, better and cheaper power is a necessity.

Many philosophical minds are so impressed; you will see them putting turbine wheels in every accessible waterfall; you see them trying to utilize the gigantic energy of Niagara; you hear of sunshine machines which concentrate the beams by large reflectors; you read speculations about the energy of the tides; you find schemers appreciating again the feeble power of the wind; and so on through the list of nature's wasted forces.

Let us not forget another project as we are in a *Franklin* Institute. There is the flash of lightning, a high tension current of so many million volts. Make it strike a huge transformer and store it up in accumulators. Well, we need a cheaper power!

I began trying to solve this problem while I was yet a student in my first term—but not that of the *perpetuum mobile*.

Students are instructed now carefully. Each inviting by-way which leads astray is marked by a finger-post; the nature of a force is thoroughly explained, using for illustration the 150,000 pounds to the square inch on the bottom of the ocean, and the comparison is made with physical work, like that done by the falling weight of a clock mechanism. They are shown that wherever energy in one form appears, energy in another form disappears. A lighthouse is planted on every cliff of perpetual motion, so that really a student cannot well invent it. As I had before this time read Liebig's popular letters on chemistry, some popular lectures of Helmholtz, and was just engaged in studying Robert

Mayer's book on the *Mechanical Equivalent of Heat*, I was thinking and living so completely in the law of the conservation of energy, that I necessarily took another direction.

My thought was this, quite in line with the practical application of Mayer's discovery :

Mechanical work is an equivalent of consumed heat; why not, by taking the heat away from water, produce a motive-power and leave behind ice?

Such a process would agree perfectly with the accepted law of the conservation of energy.

Of course, I could not find at this time a suitable way to realize the process, and I soon ceased my attempts as I was taught that there is a second law of thermo-dynamics: that the change of the heat form of energy into the form of mechanical work taking place according to the first law, can only be performed if heat can pass from a warmer to a cooler body.

As this law is not so well known by far as that of the conservation of energy, and as it is of the greatest importance in an operative ice machine, which was my aim, I will speak more about it.

The law in the present form is the result of the investigations of Sadi Carnot and Clausius.

The law is explained in the following example of the behavior of a substance in a machine devised in 1824 by Sadi Carnot:

The substance working in the machine has first the temperature of the cooler of the two bodies, which are used in the process, and is in perfect thermal insulation.

Imagine it to be a gas or vapor kept in the cylinder *D* (*Fig. 1*),* with sides, which are perfectly impervious to heat, under a piston of the same quality, but over a bottom, which is a perfect conductor of heat. The cylinder stands on the bench *C*, which is a perfect insulator for heat, so that no heat at all can pass out from it into the cylinder. The substance is now compressed on the bench. Work is spent in this

* This figure is taken from Maxwell's *Theory of Heat*, p. 139.

process and the substance becomes warmer. When it is as warm as the hot body A it is placed on that, which is supposed to keep constantly at the higher temperature, no matter how much heat goes out of it. The substance is now allowed to expand, doing work, as, for example, lifting weights. The substance, if insulated, would get cold, but as the body A has an unlimited supply of heat which passes through the bottom of ideal conductivity, the temperature of the substance is kept constant. After the substance has expanded, it is replaced on the bench and undergoes the third operation, expanding further in thermal insulation, getting cool by the way and continuing so until the temperature of the substance is that

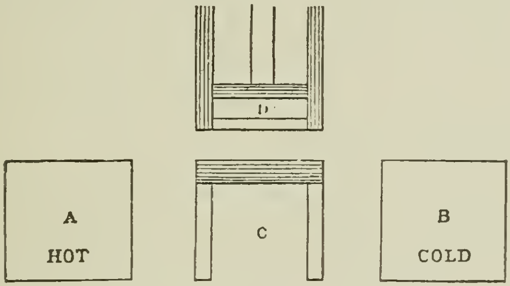

FIG. 1.

of the cold body B, which is able to receive an unlimited amount of heat without changing its own temperature. After that, in the fourth operation, the substance is placed on the cold body B and compressed, the heat due to the compression being carried away into the cold body B.

The compression is continued until the substance has again its original volume, and as far as the substance itself is concerned, the four operations have had no result, the substance being in its initial state. The total result is, that an amount of heat went out from the hot body and an amount of heat went into the cold body. A certain amount of work has been done, and an amount of work has been consumed, the difference in these two quantities of work being the useful work done.

The work done is transformed from heat, and therefore less heat than is taken from A is given to B.

As an example of an approximate Carnot process, take a steam-boat engine. The substance is water; heat is taken up from the fire gases by the boiler, heat is carried away by the cooling water in the condenser. The condensed water is pumped back by the feed pump.

Such a Carnot engine is reversible in the thermo-dynamic meaning of the word. The working substance can expand in contact with the cooler body; it can then be compressed on the bench till the temperature of the warmer body is reached; it can then in contact with this warmer body be compressed further, etc. This would mean, applied to technics: An engine can pump out cold vapor from the condenser and compress it, forming hot water in the boiler, taking up in the condenser heat at low temperature and delivering it to the boiler at high temperature by the consumption of work. Exactly this device, run at ordinary temperature by NH_3 vapor, is the ice machine, which takes away heat from freezing water.

Now, the result of the Carnot-Clausius investigation is that in the Carnot engine the ideal case of heat transmission and heat transformation is realized, and that it is not at all of importance what substance works in the engine. The efficiency does not depend upon the substance, but only upon the temperatures of the warmer and cooler bodies. If the engine works in this ideal way between 150° and 70° C., it performs exactly the same work, for each unit of heat which it receives, whether it be operated by water, starting with a tension of about 4·7 atmospheres (at fifteen pounds per square inch each), and condensing at one-third atmosphere; or by alcohol, working between 9·6 and 0·7 atmospheres; or by turpentine, the working pressure of which would vary between 1 and 0·08 atmospheres at the stated temperatures; or by carbon-disulphide expanding from 12 to 2 atmospheres; and this engine delivers to the condenser exactly the same amount of heat: and this work is, as mentioned above, the maximum: and this heat is the minimum which any machine *could* deliver, however good it may be. This very interesting statement is the result of the Carnot-Clausius law—not of experience.

This law has been proved by a demonstration which fails to satisfy the student, and it was much doubted in its early days. Helmholtz, for example, in 1854, accepted it in a lecture on the correlation of forces, with a good deal of reservation. But now, all that seems to be forgotten. Many inferences have been drawn from it, and as the inferences, where they can be criticised by experience, agree with the latter; the law stands firmly like the conservation of energy and matter. There is only one, the famous French physicist, Bertrand, who doubts the law, but he stands so isolated that his opinion is generally overlooked. He says, in his *Thermo-dynamique*, Paris, 1887, p. 266: "*Les demonstrations proposées jusqu'ici ne rendent pour moi le théorème ni certain ni vraisemblable.*" I will give you the principle for the law in the words of Maxwell, because if anything like a proof is possible, the admirable mind of Maxwell will have the best one.

Suppose a certain engine M has a greater efficiency between the temperatures S and T than a reversible engine N; then if we connect the two engines so that M by a direct action drives N in the reverse direction, at each stroke of the compound engine N will take from the cold body B, the heat H, and by the expenditure of work W, give to the hot body A, the heat H'.

The engine M will receive this heat H' and by hypothesis will do more work while transferring it to B than is required to drive the engine N.

Hence at every stroke there will be an excess of useful work done by the combined engine.

We must not suppose, however, that this is a violation of the principle of the conservation of energy, for if M does more work than N would do, it converts more heat into work at every stroke, and therefore M restores to the cold body a smaller quantity of heat than N takes from it. Hence the legitimate conclusion from the hypothesis is, that the combined engine will, by its unaided action, convert the heat of the cold body B into mechanical work, and that this process may go on till all heat in the system is converted into useful work.

"This is manifestly contrary to experience, and therefore we must admit that no engine can have an efficiency greater than that of a reversible engine working between the same temperatures."*

Such is the proof of the Carnot-Clausius law in the words of this great physicist, whom I admire. To condense it in an example: If there were a machine *M*, better than the Carnot machine, in a steam-boat, it could be run with the help of a reversed Carnot machine by the heat of the cold sea-water—which is against experience. In other words, no machine better than Carnot's is ever possible, because—there is no such machine!

The proof of Clausius is of a different character. He first generalizes an experience into an axiom:

Heat cannot travel without compensation from a cooler to a warmer body, explaining compensation as expense of mechanical work or irreversible change of any kind in nature.

After assuming this axiom, he causes the reversed Carnot and the supposed better machine, to work with another, as Maxwell does, and easily shows that the result is against the axiom.

I have the impression that Clausius was looking for a more satisfactory cause, for an internal cause in the nature of heat, for the limitation of the efficiency of the Carnot machine: perhaps he wanted natural necessity instead of simple experience, which Maxwell clearly states. But in this way he makes a much broader claim than Maxwell does. Maxwell claims a maximum rate of transformation for a working heat. Clausius also claims that, but claims further, that the remaining untransformed heat can never be elevated again without compensation. It is proper to separate in the investigation these two propositions, as that of Clausius includes or hides the first, while the first does not necessarily compel us to assume the second.

My opinion in regard to the law is as follows:

When I see that the law of Carnot-Clausius is demon-

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* From Maxwell's *Theory on Heat*, p. 152.

strated as shown and at the same time consider carefully its applications in thermo-dynamics and chemistry. I conceive the law as a general rule, which admits exceptions, and I believe that such exceptions can be found. I claim to have invented one and believe that the famous law will eventually prove to have been the first dim conception of a deeper truth.

It may happen in this case again, as it has happened with the original Carnot law. Generally, and in most cases, if heat passes from a higher to lower temperature, the same amount of heat is found at the low level. Carnot made valuable discoveries in the presumption that this was the case also if work is performed by the way. He saw the truth in the twilight. Clausius corrected the law and showed to us more of the truth, but his law may need correction yet.

Perhaps we are, in thermo-dynamics, in the situation of the leading chemists of the elder generation and in which many chemists are yet in our own day. $O + H_2$ combine and thus produce much heat. All substances produce heat when entering in combination, and no reaction can take place spontaneously—at least not "without compensation" unless heat is developed by it. Therefore, inventors look in the tables of thermo-chemistry to see from them if a reaction is possible. They do not try it, if no heat is developed by it. *But they are wrong.*

In most cases, it is true, this law holds good; but there were found exceptions to it, and the exceptions became too numerous to call the law even a rule, and, accordingly, while until lately the leading chemists have affirmed that no reaction can take place if the *entropy* does not increase by it, they nowadays teach that this condition is a special application for gases of a general law, which makes reactions dependent upon a thermo-dynamical potential, for example, upon the function ψ of Professor Gibbs.

The present Carnot-Clausius law reminds me exactly of the thermo-chemical law and of the original Carnot law.

The origin of this law, the strange way in which it is proved, and the difference between Maxwell and Clausius,

encouraged me to return to my early task of splitting up cold water into ice and useful mechanical energy.

I had to drop it because, according to this second principle, I could not elevate heat. My idea had been to use the heat for expanding a suitable substance, exactly as in ice machines, in which the heat of the freezing water volatilizes liquid ammonia or carbonic acid. I had, of course, to regain this substance, say liquid carbonic acid, and I had to do that at a lower temperature, because at the same temperature the compression would cost as much work as the expansion could deliver.

But I believed the matter unsettled, not at all on account of the reasoning about the second principle that I have just given—I was not so critical at that time—but because the theory, especially in its consequences concerning the end of the world, was repugnant to my feelings.

After much reflection and study, I think I have finally devised a method which I believe gives the solution of the problem. When I came to study the phenomena of Honigmann's well-known soda engine, I found in a certain class of chemical reactions the means of absorbing the anhydrous ammonia, or the carbonic acid, which had prevented my success.

I found, for example—not in the laboratory, but already as a well-established fact in literature—that many salts of ammonia absorb ammonia gas of a lower tension at a low temperature, that is, below the freezing point; and at a high temperature, that is, at the ordinary temperature of the atmosphere, or that of running water, develop it at a high tension. This was very inviting for further study.

An engine using ammonia should deliver in its exhaust the amount of heat, which any machine will deliver to the cooler body. But there was the advantageous circumstance that most of the ammonia combinations having little NH_3 were solids, and by absorption of NH_3 became liquids —and liquefaction *generally absorbs* heat. The liquefaction of NH_3 salts, as a fact, consumes heat. So, perhaps, the latent heat of liquefaction was equal to the latent heat of condensa-

tion (I prefer to say of absorption) of the NH_3 vapor. If that was the case, a motor without fuel was invented, no matter if it really made ice or only slightly cooled the surroundings.

I did not know the quantity of this heat of liquefaction exactly, but I estimated it by comparing it with similar data, and I came to the conclusion that favorable conditions could be chosen, in which the heat of absorption could be utilized by the opposite heat of liquefaction.

Thus I broke through the principle. Afterwards I made more satisfactory calculations for a motor serving as an example, a motor based on the same principle, but acting at high temperature, and with fairly well-known substances. I refer to the saltpetre machine which I lately described in the *Scientific American Supplement*, December 5, 1891. I think I am permitted to presume that this description is well known to the readers of the *Journal*, so that I have no need to refer to it further. I wish here to treat it chiefly in its bearing upon the second principle.

The question is: Is it true that by the use of a solution, which is formed with absorption of heat, heat can be elevated without expense of mechanical work, without compensation?

Suppose that the latent heat of a vapor (which by present methods must be delivered in the condenser to a cooler body), by the solution of a solid substance is kept latent or bound. Is it not necessary, just because it is bound, to apply in order to liberate it afterwards by evaporation, at least an equal amount of heat from an outside source?

I had this objection presented to me from so respectable a source, that I will here discuss it. You will see that this attempt to defend the second principle of thermo-dynamics must cost the first. It violates the law of conservation of energy. Call the bound heat Q_2, corresponding to a heat Q_1 which must be introduced to the working substance of a Carnot machine at the higher temperature and consists in my motor of $Q_2 + Q_L$, Q_L being the equivalent of the work to be done.

Now after the heat Q_2 is bound in the freezing mixture

and so indissolubly bound that it requires another heat Q_2 to liberate it, and after this second Q_2 *has* liberated it, it must be free. Consequently two amounts Q_2 are ready for work, the first of which might run my motor, and the remaining second might be used again and again to liberate the periodically-bound first Q_2.

But usually the objection has not this meaning. It points to the necessity of spending a second quantity of heat Q_2 for a transformation, for a work which separates the substances combined in the solution; for overcoming the force of affinity.

The objection really means that after the action of the second Q_2, there is only one Q_2.

What became of the first Q_2?

It is not in the solution; the solution exists no more.

It is not in the steam.

This steam is steam; no extraordinary substance. It is quite ordinary steam, which does not show where it came from and behaves exactly like any other steam of the same temperature and pressure made at the expense of the same heat quantity: [second $Q_2 + Q_L$]. You can secretly exchange the steam generated in my way for steam generated in the ordinary way; no physicist can find a difference. Condense my steam and it will set free the second $Q_2 + Q_L$.

The first Q_2 is not in the salt.

The salt is dry—not liquid.

Place this dry salt in the water of condensation and you will find that it cannot dissolve as it can in steam—just because the water of condensation has not this first Q_2, this latent heat which steam has and which the steam once brought to the salt, when it became dissolved in the beginning. The salt cannot dissolve except it can grasp heat from the neighborhood. The salt forms a refrigerating mixture.

It does not help the matter to say that the salt has a high temperature instead of the lower temperature at which it went in solution by the absorption of the first Q_2, and that the difference in the heat contained in the salt when it is desiccated represents Q_2. Take saltpetre and water. No doubt, the salt from the desiccator contains more heat than

the salt which went into the condenser. But the difference is not Q_2. Suppose a machine working with only 10° C. difference of boiler and condenser temperatures. As the latent heat of the salt is about 77 calories, for the condensation of one kilogramme of steam about seven kilogrammes of salt are necessary. After condensing one kilogramme of steam the salt has received about 540 units of heat. This is Q_2. Now cool down the desiccated salt in a calorimeter to the initial state and register the delivered heat. If it is Q_2 it must be 540 calories. Well, that means a specific heat of 540 divided by 10 times 7 = 7·7 for saltpetre. One kilogramme of saltpetre delivers 7·7 units of heat for 1° C. That seems to be pretty high. But now run the motor with only 5° difference in its temperatures. If Q_2 goes into the desiccated salt, the specific heat of saltpetre is 15·4 Take 1° difference and the specific heat necessarily becomes 77. You can bring it to 77,000 calories, if you please, and can vary these interesting results if you will use another solvent instead of water. I take the opportunity to report from the nearest available hand-book, 0·24 (between 0–100° C. from Regnault) as the specific heat of saltpetre.

This shows clearly that the first heat Q_2 cannot remain in the dry salt.

Consequently, the first heat Q_2

is not in the solution;

is not in the steam;

is not in the salt;

is nowhere.

The objection has destroyed it.

I think no objection can survive such an annihilating victory.

It is indeed beyond doubt that a quantity of heat which becomes latent by liquefying a salt at a low temperature, must reappear when the solution becomes solid at a high temperature. *This heat is elevated, if heat is indestructible energy.*

After this deduction it seemed to me superfluous to prove it by an experiment. But I did it when I was invited to do so under very favorable circumstances. I measured

in an electric calorimeter, which I had constructed after the device described in my American patent, the quantity of heat which is necessary to make steam from pure water and the corresponding quantity from concentrated saltpetre solution. The experiment was carried out in Germany in the laboratory of a well-known physicist and specialist in thermo-dynamics. My apparatus was not quite perfect, and gave results that were too high, but this influences the result *against me*.

The heat necessary to form steam from pure water was 621 units; to form it from solution was 334 units.

The difference is far beyond the possibility of any mistake of observation. According to theory I should have found pure water 540 instead of 621, and about 290 instead of 334 for the solution, according to the quantity of saltpetre which was dissolved.

The experiment means this: I really have made the gramme of steam with about one-half the latent heat it contains. Of course, I have not created the other half. This went into the solution before, when the temperature was low and became elevated, as I affirm.

After my views were doubly strengthened in this way, I decided to make every possible effort to secure everywhere the lawful protection for my method to supply the world with power transformed from the ordinary heat of the atmosphere.

I mention here as a detail that I have described, for example in my American patent, a method which makes me independent of the solubility of the salt. It is not necessary that one kilogramme of vapor shall dissolve so much salt that all its latent heat is neutralized. This might be inconvenient or impractical. The vapor may dissolve less and the unneutralized part of the latent heat may be neutralized by another quantity of salt, which dissolves in the liquid solvent, formed at the high temperature.

I will direct your attention to still another feature of my motor by giving an example: The chloride of ammonium, sal-ammoniac, is very soluble in liquid NH_3. It forms a compound, like so many other salts, the compound with three

molecules NH_3, namely, $(NH_4)Cl, 3NH_3$. This compound decomposes at the ordinary temperature exactly like bicarbonate of soda at a higher temperature, or carbonate of lime at the temperature of the lime kiln. The pressure which is necessary to keep the NH_3 combined with the ammonium chloride is

		mm.
At	— 6°	730
	+ 6°	1,480
	+ 8°	1,800

Now, imagine that you wish to run a machine with NH_3 vapor taken from the decomposing salt at + 6° and combining with it again at — 6°.

The vapor enters the engine with 1,480 mm. pressure, and may expand along the adiabatic line, until it has 730 mm., that is an expansion of only 1 : 2. The temperature, when the absorption pressure is reached, will be about — 36°, but the absorption takes place at — 6°. With the temperature of — 36°, according to Carnot, the heat Q_2 should be taken away or elevated, but with the — 6° it appears. The heat jumps up at once 30° on contact with the salt. If this machine acts with a range of temperature of 42°, the elevation of heat is necessary only through a range of 12°. Other salts show this peculiarity even more strikingly. The neutralizing of the heat at — 6° and its reappearance at + 6°, which happens after the first jump, seems to be very similar to an action of chemical affinity.

From this point of view, that chemical affinity intervenes in my motor, all that is strange in the elevation of heat disappears. There is no heat. The heat is transformed into another form of energy, and is re-transformed into heat at a high temperature, and it cannot surprise us if such other energy does not behave as heat generally does.

I can express the principle of my motor in this way: Carnot's heat Q_2 can only be elevated by another thermodynamical cycle. Thus it costs mechanical work. I substitute for that a thermo-chemical cycle, which costs no mechanical work. My motor in its process perfectly agrees with the theory of Maxwell, in that it transforms as much

heat as the Carnot machine during its action, and it is only after this action is completed that my motor elevates the unused heat against the principle of Clausius, and does this by going outside of the domain of heat.

There is, indeed, nothing unreasonable in the idea of elevating without work, the heat, which in Carnot's cycle is not transformed. If one considers it as an unavailable heat it is very probably simply *called* heat, but is in reality some kind of energy which corresponds at a certain temperature to the quality shown by a substance or which even makes and constitutes this quality. Heat is a collective name applied to such kinds of energy as can raise the temperature of a substance, if they are spent by a first substance. It is remarkable that heat never has been observed. Temperature has been observed, but not the heat which causes it. Even instead of such heat, which we call free in contradistinction from latent, at the very moment of the change from one body to the other, only a quality of a substance has been *observed*. We *presume* and *construct* the heat as a thing behind the phenomenon, like the god Æolus was presumed or constructed behind the change of the winds. Therefore, I often prefer to say energy instead of heat, in order to speak with more exactness.

Now, the so-called heat or energy in the working substance of Carnot consists of two parts Q_2 and Q_L. The energy Q_L is geared into the intrinsic wheel-work of nature in such a way, that sinking down to a lower temperature, it can change into work. The part Q_2 is connected and geared in such a way that going to a lower temperature, it *cannot* change into work. Why should not, therefore, in turning the wheelwork backward, the elevation of the energy Q_L (which is a *regeneration*) *cost* work, just because of this connection, and the elevation of Q_2 cost *no* work because it moves indifferent to mechanical work?

In my motor, I disconnect the two parts of the energy; I elevate the part which is *unavailable*, and in so doing, I need not spend work, but, in consequence of it, can never do work by it; can never avail myself of this part. Does not that appear reasonable?

Gentlemen, I have explained now the reason which impelled me to go forward with my motor. I have proceeded with full consideration of the laws of nature. I have avoided the slightest attempt to invent perpetual motion according to the first law of thermo-dynamics. I have aimed to obtain mechanical work by simple transformation of heat.

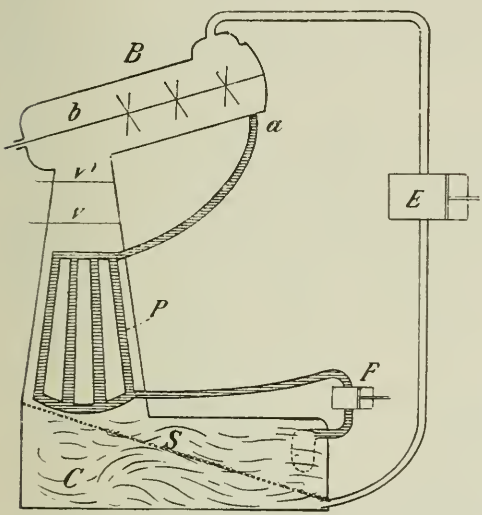

FIG. 2.

EXPLANATION.—The boiler *B* receives a solution at *a* and evaporates it. The solid residue is desiccated and moved forward by help of a suitable stirring device *b*, to the lower end, with the valves V_1 and V_2, which are operated alternately and keep up the separation from the space of low-pressure over and in the condenser *C*. The vapor goes to the engine *E*, and exhausts into the cold lye at *C*. The concentration and low temperature of this lye is kept up by the continuous solution of solid resting on the sieve *S*. The lye is brought back again to the boiler by the feed-pump *F*, passing the pre-heater *P*. This pre-heater is arranged as an example of the possible devices which remove the heat of the warm solid coming from the boiler by contact with the cold lye coming from the condenser; thus bringing the solid to the temperature of the condenser with no loss of heat. (For details, see U. S. Patent, No. 456,831.)

But I take heat of a low temperature. I knew the obstacle of the second principle of thermo-dynamics, but I thought that it might be advisable, under special circumstances, to leave the plain and popular routes of travel, and to try as a solitary explorer a new, untrodden path; and

As this second principle is proved in such an extraordinary manner;

As heat which becomes latent at a low temperature, really reappears at a higher one;

As the latent heat of a vapor makes a wide leap upward by mere contact with an absorbing substance;

As my method, notwithstanding, agrees perfectly with Maxwell's theory and only contradicts the axiom of Clausius; I have resolved that my motor must be built.*

I have lately found another view, which weakens the second principle and brings my method out of its exceptional position. Probably no physicist, Clausius certainly not, makes a distinction between the heat which is in the substances and radiant heat. All scientists hold the idea as a self-evident one, that every body radiates heat against every other body.

A chair, a book in a room, radiates heat, but receives as much by radiation. Now, I beg to remind you of the universally-known experiments of Hertz, the demonstration of Maxwell's electro-magnetic theory of light, and to affirm that: Ordinary heat is the same as radiant heat; radiant heat is the same as radiant light; radiant light is the same as radiant electricity; radiant electricity is ordinary electricity in alternating current; ordinary electricity can be transformed perfectly into mechanical work.

And now another view of radiant electricity, which strengthens the first one.

According to the second principle, no thermo-dynamic machine can produce work if it is not in contact in one part with a warm, and in another part with a cool substance. If the whole machine is surrounded by the same atmosphere with the same temperature everywhere, no action is possible. But I make such a machine run without connecting it with a cooler body. As by radiation everything is connected with everything, the equally tempered surroundings are no obstacle. I take the two reflectors of the old experiment of Mariotte (*Fig. 3*).† In the centre of the one I place instead of the thermometer, the condenser of a little machine, surrounded by warm air like the boiler; in the centre of the other I put a piece of ice. The ice condenses the vapor in the distance, as if the reflector transferred the cold of the ice into the condenser.

* The diagrammatical sketch, *Fig. 2*, shows its appearance in its simplest form.

† From G. M. Hopkins' *Experimental Science*, p. 193.

This experiment, extended to its consequences, seems to show that if there is a cool place anywhere, a warm place equally tempered around a whole machine, can develop mechanical power. It is not necessary to have ice or any cool body connected by radiation with the condenser. Connect the condenser with nothing; have only one reflector and turn it against the endless space of the sky, and the machine runs equally well. On a larger scale, this means the sunshine machine of the hot countries inverted for night-time and for our climates. I might take out a pâtent for it: a new and improved method of catching cold.

This machine interests us here as a parallel to my motor. It may be constructed as a liquid ammonia machine surrounded by warm air, working with the heat of the atmosphere. That it works can be seen from the

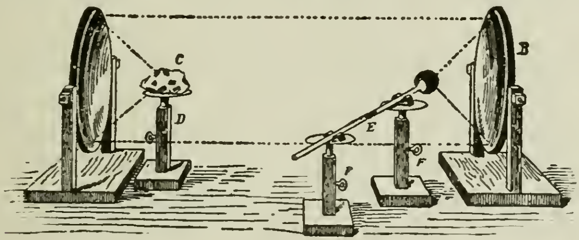

Fig. 3.

fact that a thermometer without any reflector, laid on a box under the free sky, stands lower than another one, near the box if screened from the sky, often by about 20° F. If some one should say that the condenser itself is here Carnot's cooler body, I answer that it is in my machine the same

It seems that the enforced radiation, which might be taken to mean an increased loss from the globe, makes the machine run. But, considered more carefully, it appears that if the condenser enforces radiation, the boiler prevents it. The heat taken by the boiler from the atmosphere leaves so much less to be radiated, and as the condenser radiates less heat than the boiler receives, on account of the mechanical work performed, the radiation from the globe is not increased but diminished. My motor does exactly the same thing. It also takes heat from the store of the globe and prevents it from being radiated away as long as it has

the form of other energies, such as mechanical work, electricity, chemical difference of aluminum and oxygen, and so on. Much more might be said about the parallel between the radiation machine and my motor. I only mention that not even the walls of the condenser are Carnot's cooler body, the working NH_3 itself, in which the condenser has no walls, condenses.

If you will consider this radiation machine working. we will suppose, with the condenser and the boiler in the same air current, you will be compelled to admit either that the second principle is broken down and therefore no longer an obstacle to my method, or that the second principle must be extended until it covers not only the contact, but also the mere distant existence of a cooler space, in which sense it is no longer an obstacle to my motor.

When the principle is extended so far that it allows a machine to work having the condenser in the focus of Mariotte's reflector, where on a screen a lump of ice would appear; that is, to work with the mere image of a cold body, or, as in my inverted sunshine machine, radiating into infinitely distant space, it will not do me any harm.

Gentlemen, I have spoken this evening chiefly of the second principle, and much less of the machine which perhaps equally excites your interest. I did so, because I thought I would better satisfy the members of this scientific institute, if I put aside the mechanical features of the motor, which may change in time, and are very simple ones. I felt obliged to subject to criticism the theory which seems to stand in the way of my thermo-dynamical method.

There has not yet been found a mistake in the processes and details of this method; it has been examined by professional men, friends of mine, by scientists like Prof. Thurston, and, as I am officially notified, by the thermo-dynamical authorities which the American Patent Office consults. Nothing against the processes of the method could be said. except that this general idea, this axiom, which can be applied without hearing more than the *claim* of the method, this dogmatical second principle certainly must kill it, if it is true.

Therefore, I felt impelled to throw some light on this axiom.

THE NICARAGUA CANAL.

By GEO. W. DAVIS,
General Manager Nicaragua Canal Construction Company.

[*A lecture delivered before the Franklin Institute, January 8, 1892.*]

[*Concluded from p. 20.*]

BEGINNING OF WORK OF CONSTRUCTION.

Although some months elapsed after completion of the final surveys before the voluminous plans and detailed drawings were prepared and approved by the Nicaraguan Government, and the work of construction was permitted to begin, yet a corps of engineers was kept constantly employed and when work was initiated, the force only needed to be properly augmented. The first reinforcement was sent out in May, 1889, and others followed from time to time as necessities required. The work itself was not formally inaugurated until the 8th of October of this year, but much valuable preparatory work was done meanwhile, such as the commencement of the erection of permanent quarters, wharves, store-houses, clearing the ground and accumulating supplies, tools, etc.

The necessity of securing a safe entrance to the old harbor (which, until 1860, was easily accessible to vessels of upward of twenty feet draft), was realized as indispensable to economical and rapid progress, and the first work begun of actual construction was in execution of the engineers' plans for restoring the harbor. One of the means to this end was the erection of a breakwater for protection of the entrance. This massive work which will ultimately absorb many hundred thousand cubic yards of the rock excavated from the Divide cut, has been pushed out about 1,000 feet, and is continually being filled in with brush mattresses, rock and hydraulic cement concrete. Quarters for accommodation of the workmen and storage

for supplies were erected near this work. A railroad track was laid upon the breakwater as it advanced, and was extended landward to a point whence was brought the building material and other supplies. In this breakwater, creosoted piling only was used in the frame work, as the marine worm (*teredo navalis*) would soon destroy unprotected wood.

The bar in front of the old San Juan harbor, which, in 1860, was closed by a sand spit formed across its entrance, has since been known as one of the most dangerous on the coast. From the beach to and across this bar the breakwater had to be constructed, and therefore it encountered the full force of the waves, but it has been carried forward through the heavy surf, without stopping at all on account of the weather, and without accident of any kind. As the pier advanced, it afforded a partial shelter to the beach to leeward, and also served as a barrier to the moving beach sand which, impelled by the waves and prevailing winds had formerly been driven constantly to the westward, and so built up and maintained the sand spit that thirty years ago closed the old port San Juan.

This artificial interruption to the operation of the winds and current, which were always active in bringing sand for building and renewal of the beach, permitted countervailing forces of nature to come into play; and the result was that, by the time the pier had been pushed out 600 feet, the sand beach under its lee was swept away and an open channel formed, communicating from the open ocean to the old harbor, now restored to the extent of permitting the entrance of light draft sea-going vessels, and this at a point where six months before was a sand bank three or four feet above the sea level. The attainment of this result was without assistance of a dredge, or any other artificial aid than that afforded by the breakwater. A most important deduction is evident from this experience, namely: That the plan devised by Mr. Menocal for the restoration of the port of San Juan, which some engineers had declared to be impracticable, is sound.

The building of this important work has steadily pro-

gressed as materials were available, and its total length is now 1,000 feet. The outer end is in twenty feet of water, and a force is constantly engaged in filling in the spaces between the piles with mattresses, rock and concrete. The depth of the channel under the lee of the pier reached ten feet when the structure had been extended to 800 feet. In the winter of 1890–91 a dredge increased this depth to about fifteen feet, and this has been maintained since, except in very restricted areas, which are easily deepened by the dredging machines. The first deep sea vessel to enter the restored port was the steamer *Sverdrup*, with a cargo of machinery, etc., on the 7th of January, 1891, and since then many other vessels have frequented the port.

During the summer of 1889 permanent buildings were begun, and building constructions have been in progress ever since. The structures are all of wood (pine from the United States), and roofed with corrugated galvanized iron. The offices, quarters and hospitals are all ceiled and painted inside, have wide verandas outside, and are neat and comfortable. All the permanent buildings so far erected are in the immediate vicinity of San Juan, for at this point is located the general headquarters, and here have been concentrated the most important operations.

The buildings now occupied consist of five groups (all near the sea-beach), and have the floor space stated below :

	Buildings.	*Sq. Ft. Floor.*
Headquarters,	8	13,986
Hospital,	10	14,174
La Fé Depot,	8	21,864
R. R. Headquarters,	9	18,778
Camp Creek,	4	7,100
Total,	39	75,902

Besides the above, there are numerous and extensive wharves, equipped for unloading freight, sheds, small outhouses, water tanks, etc. The machine and smith's shops are equipped with a varied and extensive assortment of modern machine tools, and a tramway connects the more important of these establishments.

The concession allows to the enterprise all the lands

required for any and all purposes incidental to the construction of the whole work, including accessories, and this without charge or cost where lands required belonged to the Government at the date of the concession. In case the lands appropriated by the canal belonged to private owners, compensation is required to be made, the amount to be determined by the usual proceedings of condemnation and expropriation. The 1,000 *manzanas* of land (1,723 acres) have already been placed at the disposal of the company, and payment has been made in the sum of $50,000, as provided in the concession. East of the lake, and all the way to the Atlantic Coast, the whole district is unsettled, save by a few fruit growers, and as the title to the lands still vests in the republic, the cost of expropriations will be merely nominal.

Work in clearing the canal line of forest growth was begun near Greytown in January, 1890, and for a distance of about ten miles back from the coast, the clearing has the full width of 486 feet. The same work was commenced on the west side of Lake Nicaragua in the month of November, 1890, and for nine miles this ground is made ready for the active construction work.

The necessity for a telegraph reaching to the interior, connecting with the telegraph system of the country and the ocean cables, very soon became apparent. This was one of the first works commenced; it was soon pushed through to Castillo, with its loops amounting to sixty miles. The first ten miles of the line back of San Juan was across a very difficult swamp, where the work was most arduous; the poles, which were made of native timber, were difficult of procurement, and together with all other supplies had to be carried by men wading in water from two to four feet deep. The water was so deep that in some places poles could not be set in the earth at all. In such cases they were secured to tree stumps, and otherwise supported by wire guys. Through the hill country the line was also an expensive one to build, and is very difficult to maintain. To ensure immunity from falling timber, a clearing of the forest was necessary 100 feet wide. All the offices and

more important camps and stations are in telephonic communication.

As the heaviest body of work to be accomplished on the whole line is concentrated within a distance of three miles, at what has been designated as the Eastern Divide, and as the time required to complete the canal is measured by the time spent in opening this deep cut, it was felt to be important to install a plant for this heavy rock cutting at the earliest date possible. But so great were the difficulties of transportation of heavy machinery, etc., from the harbor to the site of this heavy cutting, it was at once apparent there was no alternative to be considered but the immediate construction of a railroad. This was begun in the summer of 1890. It extends across what had always been considered an impassable swamp, and for the first ten miles there are but about four miles of hard ground. Soon after beginning heavy rains set in, and the swamp was flooded to a depth of from one to four feet. No earth for filling could be had from along the track, and so all had to come from a distance, brought by train, and these conditions necessitated a reversal of the ordinary proceeding, *i. e.*, laying the track first and making the required embankment afterward.

To accomplish this, novel methods were employed. A heavy corduroy of logs, gotten from the neighboring forest, was laid for many miles. These were rolled, floated or dragged by man-power alone to the line of proposed track, and there arranged as compactly as possible. Upon them were laid longitudinal stringers, also consisting of native tree trunks—the straightest that could be found. Then came the railroad ties, resting on the stringers, and lastly the steel rails, all spiked down. The cars, loaded with sand, were then run out over the log embankment and there unloaded, the sand being packed into the interstices and under the ties, which were raised gradually by the workmen until the desired grade was secured. There were six miles in all of this swamp work. Except in filling the sand trains, no other power was used than that of men, and nearly always the swamp water was above knee deep and

often to the waist or armpits. The material used in grading and ballasting the road-bed was taken from the canal prism, near the harbor, and delivered along the line by trains of cars, loaded by means of a steam shovel or navvy, capable of delivering upon cars 1,300 cubic yards per day.

There are several places along the line, where streams and other water-courses are crossed. These are spanned by pile bridges, and a powerful steam pile driver has been used in their construction. The length of road completed to date is eleven miles—the most difficult of the whole line—and seven miles remain to be completed in order to reach the Divide. There are several miles of side track, switches, etc., already in place.

The road is equipped for construction work, and supplied with four locomotives, fifty cars, steam shovel, ballast unloader, jacks and other requisite appliances. All the cross-ties and bridge timbers are of northern pine, and charged with sixteen pounds creosote oil to the cubic foot. At the railroad terminus on the harbor is a fine wharf, 264 feet long, built in the best manner of creosoted timber, and equipped with modern steam conveniences for handling freight rapidly.

The survey for the remainder of the railroad line, extending to the San Juan River at Ochoa, has been completed: in fact, there have been two lines surveyed and profiles prepared in sufficient detail to enable a close estimation of cost. Between Lake Nicaragua and the Pacific the railroad line is also located, and everything made ready for its construction, which, it is realized, must precede the beginning, upon a large scale, of the work of canal construction itself.

In the summer of 1890 there was purchased from the American Contracting and Dredging Company, the very extensive and valuable plant used so successfully on the eastern end of the Panama Canal from the year 1881 to the collapse of that enterprise in 1888. The property consisted of seven dredges, the most powerful ever built, two fine tug boats, twenty lighters, several launches and a vast quantity of tools, spare parts, materials for repair and renewals,

an entire machine shop, stationary engines, pumps, etc. Many of the articles are in abundance sufficient to suffice until the Nicaragua Canal can be completed. During the autumn of 1890 this property was transferred to San Juan del Norte—all save one of the oldest and least valuable of the dredges, which was lost at sea. Upon the arrival of this plant, portions of it were immediately equipped for work, and three of the dredges have since been in use for various periods—two upon the line of the canal proper and a third in increasing the depth of water at various points in the harbor and upon the bar. The canal line to the width of 280 feet and depth of 17 feet has been opened for 3,000 feet inland from the harbor, the material excavated being sand almost wholly. No buried wood or other obstructions to free dredging have been found. A powerful suction dredge for working upon the bar at San Juan has been constructed in Scotland for this company, and is ready to be sent to its destination.

All the engineers employed on the line have been men of known and tried ability. Those in positions of chief responsibility have had extensive practice in works of engineering construction in the United States and the tropics. All are graduates of the best technical school. Mr. A. G. Menocal, who has been connected with the enterprise from its organization, is the Chief Engineer.

The engineers, administrative staff, surveyors, nearly all the skilled mechanics, foremen, etc., have been hired in the United States and sent out under contract for at least a year's service. The common laborers are of two classes—the natives of Central America and the negroes from the island of Jamaica. All have been housed and fed by the company, and supplied with medicine and hospital attendance free. The rate of wages paid to common laborers varies from twenty to thirty *soles* per month (the Colombian *sole* has a value of about seventy-five cents gold), and it is evident from experience gained that an abundance of acclimated labor, entirely adapted to the company's needs, is readily obtainable from the localities named.

Mention has been made of a steamboat company

operating a line of boats upon the San Juan River and Lake Nicaragua. As the owner of these boats held an exclusive privilege for navigating the San Juan River and Lake Nicaragua by means of steam vessels, it became necessary for this company to acquire the property referred to. This was done in the fall of 1889, and the line has since been operated in the interest of the Construction Company. The franchise is a very valuable one, aside from its bearing upon the construction of the canal.

SUMMARY.

The company has gone to its work of building the canal in a plain, unostentatious, systematic manner, and although nearly all accomplished to date may be described as preliminary, yet a very important advance has been made. These results may be summarized as follows:

(1) The completion of the final surveys for location and construction.

(2) The subterranean examination of the strata requiring removal, by means of borings with the diamond drill.

(3) The restoration of the harbor of San Juan del Norte to the extent of securing an easy entrance to the port for vessels of twelve feet draft.

(4) The construction of extensive wharves and landing facilities.

(5) The erection of permanent buildings for offices, quarters, hospitals, store-houses, shops, etc., having a floor area of an acre and three-fourths.

(6) The building of a large number of temporary camps along the line for accommodation of employés.

(7) The completion of a telegraph line permitting ready communication of the New York office with any part of the work.

(8) The clearing of the canal line of timber for some twenty miles.

(9) The completion of surveys for location and plans of construction of the railroad system, and the construction and equipment of eleven miles of this line.

(10) The acquisition by purchase of the most valuable

and powerful dredging plant to be found in America, under one management.

(11) The fitting up and operation of this plant and the opening of nearly a mile of the canal.

(12) The acquirement by purchase of the valuable and exclusive franchise for the steam navigation of the San Juan River and Lake, together with the extensive plant of the Navigation Company, consisting of offices, lands, steamboats, tugs, lighters, repair shops, etc.

(13) And lastly, what is felt to be the most important result of all is the demonstration, secured by experience, of the salubrity of the climate, the efficiency of labor and the sufficiency of the estimates of the chief engineer for the harbor and canal dredging and railroad work.

Finally, the Government of Nicaragua has formally made acknowledgment of the fact that the company has fully complied with the requirement imposed by the canal grant, which provides that the work of construction shall not be considered as commenced unless $2,000,000 are expended in the first year. This formal acknowledgment confirms the company's title to the concessionary rights for a term of ten years in which to complete the canal and open it for traffic.

FINANCIAL.

The financial questions of inter-oceanic communication across the American Isthmus have been answered, in a very great measure, by the results realized at Suez.

But before considering what has there been demonstrated, an elementary principle of commerce may properly have some attention. Facilities for the transaction of commerce have always induced its development and growth between points at which the primal conditions for its transaction have been found; that is to say, diversity of natural or other resources and a production beyond the requirement of the producer, together with the desirability of its acquisition by the non-producer, as for instance the production of a food supply on the one hand and of manufactured goods on the other, or any other analogous supply and demand.

The operation of this principle has ensured the growth of population, and the extension of empire along the line of water-courses and of oceanic waterways in the past, and in the present time has had one of its most remarkable illustrations in our own country almost within the personal observation of some to whom I am now speaking.

It determined the growth of Chaldea, Assyria and Babylonia along the course of the River Euphrates and of Egypt along the Nile. It made Tyre and Carthage and Venice in turn mistresses of the commerce of the world and mighty political powers, because of their nautical skill and location upon the Mediterranean Sea. It gave the Hanse Towns their despotic power in the Middle Ages, Holland her wealth and Great Britain her prosperity and wide extended empire. England's ships brought to her shores the commodities of foreign climes, some of which she sold at a gain for her services as merchant, but most of which she transmuted by the alchemy of coal and iron and labor, in all of which she was rich, into commodities other and different from what she had received—far beyond her own needs, but needed in other and distant countries with which her fleets gave her the readiest and cheapest communication.

The growth of England's commerce, since the development of steam as a motive-power made her stores of coal and iron the auxiliaries of her commercial enterprise, has been almost beyond belief; in 1839, the aggregate of her imports and exports amounted to £115,281,580; from that time, on the use of steam became more and more general both as a means of transport and as an aid in manufactures. In 1873, when the movement seemed to culminate, the aggregate of England's commerce amounted to £625,128,170. It was the facilities which England afforded for the transaction of commerce, as an ocean carrier and as a converter of raw goods into available fabrics by the use of machinery, which has developed this enormous growth and yielded her its tribute of wealth.

But I have mentioned the illustration of the principle in our own country. In 1826, the first railroad in the State of

New York was built from Albany to Schenectady, a distance of seventeen miles; in 1830, there was still only twenty-three miles of railroad in the United States; in 1832, the total number of miles in operation was but 229. Since then the growth of our railroad system has been rapid, and at the present time we have nearly 170,000 miles of railway, equipped with 30,000 locomotives and 1,000,000 cars, carrying more than 700,000,000 tons of merchandise and 500,000,000 passengers annually.

In 1832, when there was but 229 miles of railway, the population of the country was between 13,000,000 and 14,000,000, mostly distributed along the seaboard, the borders of the Great Lakes and the courses of the great rivers. To-day it amounts to 65,000,000, distributed wherever a railway will carry a man or bring to market the product of his fields or forests or mines. The entire country has reaped the advantage, and growth and prosperity is found not only in narrow strips of country bordering the waterways, but everywhere and over its entire breadth—and not only is the enormous increase and spread of population over inland territory attributable to the facilities afforded for transportation, but the growth of great cities upon the seaboard and even in the interior, to an importance comparable with that of the great cities of Europe, is owing entirely to the facilities the railroads have afforded for interchange of commodities between all parts of our country and between the country at large and the world.

The growth of our foreign commerce, too, is not less remarkable than that of England, and is entitled to as ample provision for its future development. Since 1844, it has grown from $208,350,438 to $1,647,130,043 in 1890, and this year it will exceed $1,800,000,000—a ratio of increase even greater than that of Great Britain during her phenomenal period.

But to return to the demonstration of financial results as indicated by the practical operations of the inter-oceanic canal at Suez.

Statistics show that between seven-eighths and eight-ninths of the actual tonnage passed through that canal

originates at, or is carried to the Atlantic ports of England, Germany, Belgium, the Netherlands, etc., for which the economy of distance traversed does not in any instance exceed 4,400 miles, and in many instances is not more than 1,200 miles.

The saving of distance by the Suez Canal over the Good Hope route between

	Miles.
Liverpool and Bombay is	4,400
Calcutta is	3,681
Hong Kong is	3,331
Yokohama is	3,368
Melbourne is	1,200

Between Liverpool and Auckland, New Zealand, the distance is 1,395 miles less by Nicaragua than by Suez.

For a saving then of 1,200 to 4,400 miles distance in transportation, the commerce of Great Britain, Germany, Holland and Belgium, to the extent of 6,000,000 tons per annum (and the amount is steadily increasing with experience of the advantage), finds it profitable to make use of the Suez Canal, and to pay its tolls.

The Nicaragua Canal offers to the commerce of the eastern ports of the United States, trading to Pacific ports, the advantage of 3,000 to 9,600 miles in distances saved, and to those of Europe from 1,036 to 6,100 miles. The conclusion which these premises warrant is so evident that it seems almost unnecessary to state it. Certainly commerce will avail itself of such an advantage.

But to what extent may it be expected to do so? On this point estimates have differed widely, from as little as 1,901,250 tons to as much as 10,262,494 tons per annum. The smaller estimate was made in 1880 in opposition to the Panama Canal scheme and, as has since become apparent, in the adverse interest of the transatlantic railroads; it was at once shown to be wilfully or ignorantly inadequate and should have no consideration whatever. The next lowest estimate was made in 1890 and amounted to 4,387,000 tons. A careful study of the commerce carried on within the area made more accessible to trade by the Nicaragua Canal, shows that the commerce there existing

amounts in the aggregate to more than 18,000,000 tons per annum, from which total the canal is to derive its share of business and its revenue; with these facts in view I shall not be regarded as unreasonable in claiming that it will have not less than 6,000,000 tons per annum of business as soon as it is open for use; for transit of ocean-going vessels by an inter-oceanic canal is no longer an untried experiment as it was when the Suez Canal was first opened to commerce. Commerce will not now wait to ascertain 'how it works;" that has already been learned, and business men will be ready at once to avail themselves of the advantages proffered.

If the canal tolls be fixed at $2.50 per ton, this amount of traffic (6,000,000 tons) will yield a gross revenue of $15,000,000.

The cost of maintenance and operation of the canal, after the completion, cannot be large. The route is made up principally of broad stretches of water with natural banks, or of cuttings through solid rock which once made will be permanent; and there are no sands drifting from widespread desert plains, as at Suez, to fill its channel continually and make necessary large and unceasing expenses for dredging. The cost of maintenance must, from the nature of things, therefore be moderate. The operation of the lock of the Sault Ste. Marie Canal, which passed nearly 7,500,000 tons in the season of 1890–91, together with all other expenses of that canal for that year, amounted to $45,417. Allowing $50,000 for each of the six locks of the Nicaraguan Canal for operating alone, and making a similarly liberal allowance for maintenance, administration and all other expenses, the total annual cost cannot exceed $1,500,000, which, on an annual traffic of 6,000,000 tons at the rate of toll suggested, shows a net revenue of $13,500,000, or five per cent. on a total capitalization of $270,000,000, to be realized upon the attainment by the enterprise of such a condition of advancement as will afford opportunity for demonstration of its capabilities.

But this estimate of 6,000,000 tons which I have mentioned as the probable tonnage of the canal at its opening,

must not be allowed to limit in your minds its possibilities, or rather its probabilities, which is the more fitting word.

With the opening of the route not only will a new thoroughfare be provided, but new fields will be opened to commerce by the more advantageous provision for its transaction. In this respect the opportunity is unique. The countries chiefly brought into contact by the Suez Canal are old, densely populated and have few new or untried resources awaiting development. On the other hand, western North and South America, Australia, Corea, Japan and eastern Siberia, the abodes of vigorous, rapidly increasing and enterprising peoples, possessing vast resources awaiting development, the magnitude and value of which are already shown to be incalculable by such essays as have been possible under existing conditions, by the canal are brought into closer connection with great commercial centres by a water highway traversing a country unsurpassed in its natural attractions, equally rich in all the material endowments of nature, which, possessed of adequate facilities for travel, must become a resort for travellers from all parts of the world. It would seem that the essential conditions for an unprecedented growth of population, commerce and material prosperity exist here to a degree never before exceeded.

The projected Russian railway, from the heart of that great empire to the port of Vladivostok on the Sea of Japan, will bring into close commercial relations with the United States, all of Asiatic Russia and much of the interior of Central Asia now practically inaccessible to foreign commerce. The lower valley of the Amur, before that river turns northward to its *debouchement* into the sea of Ochotsk, possesses an excellent climate and an exceptionally fertile soil; the same may be said of the soil and climate of extensive areas about the headwaters of other great Siberian rivers further east, flowing to the Arctic Ocean, and many of the richest mines in the world are found in the neighboring mountains, but by reason of remoteness and inaccessibility these resources have been but imperfectly developed. An

enormous expansion of the trade of this region is certain to follow the provision of adequate means of communication, and this development will be vastly stimulated by the opening of an isthmian thoroughfare.

Corea now has a population of 10,000,000, and her trade may be expected to assume important proportions. In 1884, the total value of her exports and imports was but $1,500,000. In 1889, it had risen to over $4,500,000, an increase of more than 227 per cent.

The commerce of Japan, although already of a considerable magnitude, it is to be remembered, is as yet in its infancy, and therefore susceptible of development in a ratio more than normal. As a fact, the commerce of that empire has doubled in the last five years, and its manufacturers are now commencing to buy our cotton for their looms. Japan has a population of 40,000,000, and its people are intelligent, enterprising and progressive. In 1889, its commerce amounted to about $136,000,000, or say $3.40 per capita. The commerce of the United States amounts to over $25 per capita.

The most healthy and most attractive portions of the Spanish-American republics are those bordering on the Pacific Ocean, occupying the western slopes of the mountain chain which traverses the continents. This entire section of country will be brought by the canal nearer to its present markets (which are chiefly in Europe), say from 2,000 to 6,000 miles; but what is of greater importance, it will also be brought from 5,000 to 10,000 miles nearer to New York than at present, and at the same time 2,700 miles, or substantially the width of the Atlantic, nearer to New York than to any European port. Such an advantage cannot fail to have the effect of developing enormously the commerce between these countries and the United States, which at present is but limited.

By the facilities thus afforded for the transactions of commerce, the industries of the several countries will be stimulated and developed, and immigration with its beneficial effects to South American shores as well as to those of California, Oregon, Washington and Alaska will follow. A

great increase of population along the entire western coast of the American continents, together with the growth of commerce which will naturally accompany it, will unquestionably result from the completion of the canal; what it will actually amount to may perhaps be indicated by the example already cited of the development of the United States through the extension of her railroad system. At the same time the markets of the western shores of America will be opened to a coastwise trade with our Atlantic ports; what its aggregate will be is suggested by the fact that such a trade already exists with the West Indies to the extent of 500,000 tons per annum.

In whatever direction attention is turned, the substantial elements are apparent of an enormous and unprecedented commercial development, in connection with the opening of the Nicaragua Canal, such as makes an estimate of results based thereon seem fabulous, and for that reason to be avoided. Enough has been shown to prove that the canal will have an abundant business, from the day when a vessel may pass through it from ocean to ocean, to pay interest on all of the capital ventured in its construction, and to richly reward its projectors.

NATIONAL CONSIDERATIONS.

It is appropriate that your attention be also invited to some of the national aspects of this enterprise.

Ex-President Grant, writing for the *North American Review*, for February, 1881, expressed his convictions as follows:

"In accordance with the early and later policy of the Government, in obedience to the often-expressed will of the American people, with a due regard to our national dignity and power, with a watchful care for the safety and prosperity of our interests and industries on this continent, and with a determination to guard against even the first approach of rival powers, whether friendly or hostile, on these shores, I commend an American canal, on American soil, to the American people and congratulate myself on the fact that the most careful explorations have been started,

TABLE OF DISTANCES, IN NAUTICAL MILES, BETWEEN COMMERCIAL PORTS OF THE WORLD, AND DISTANCES SAVED BY THE NICARAGUA CANAL.

Compiled from Data furnished by the United States Hydrographic Office. Length of Sailing Routes, Approximate Only.

Between	Around Cape Horn for Sailing Vessels.	Via Magellan for Full Powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Route.	Advantage over Steam Route.
New York and San Francisco, .	15,660	13,174	—	4,907	10,753	8,267
Puget Sound, . .	—	13,935	—	5,665	—	8,270
Sitka, ...	—	14,439	—	6,177	—	8,262
Bering Straits, .	—	15,705	—	7,402	—	8,303
Acapulco, . . .	—	11,555	—	3,045	—	8,510
Mazatlan, . . .	—	12,037	—	3,675	—	8,362
Hong Kong, . .	—	—	13,750	10,692	3,058	—
Yokohama, . . .	—	—	15,217	9,227	5,990	—
Melbourne, . . .	13,760	12,860	12,830	9 862	3,898	2,998
Auckland, N. Z.,	12,600	11,599	14,069	8,462	4,138	3,137
Honolulu, S. I., .	15,480	13,290	—	6,417	7,063	6,873
Callao, ...	—	9 640	—	3,744	—	5,896
Guayaquil, . . .	—	10,300	—	3,227	—	7,073
Valparaiso, . . .	9,420	8,440	—	5,014	4,406	3,426

Between	Around Cape Horn for Sailing Vessels.	Via Magellan for Full Powered Steam Vessels.	Via Cape of Good Hope.	Via Nicaragua Canal.	Advantage over Sailing Route.	Advantage over Steam Route.
New Orleans and San Francisco,	16,000	13,539	—	4,147	11,853	9,392
Acapulco, . .	—	11,920	—	2,285	—	9,635
Mazatlan, . .	—	12,402	—	2,915	—	9,487
Callao, ...	—	10,005	—	2,984	—	7,021
Valparaiso . .	—	8,805	—	4,254	—	4,551
Liverpool and San Francisco, .	15,620	13,494	—	7,627	7,993	5,867
Acapulco, ...	—	11,875	—	5,765	—	6,110
Mazatlan, ...	—	12,357	—	6,395	—	5,962
Auckland, ...	12,130	11,919	13,357	11,182	948	737
Guayaquil, . .	—	10,620	—	5,947	—	4,673
Callao, ...	—	9,960	—	6,464	—	3,496
Valparaiso, . .	9,380	8,760	—	7,734	1,646	1,026
Honolulu, ...	—	13,610	—	9,237	—	4,473
Yokohama, . . .	—	—	14,505	11,947	—	2,558

Length of Canal (in nautical miles), ...	147
New York to Eastern Port of Canal, ...	2,060
Liverpool, ...	4,780
Hamburg, ...	5,127
Havre, ...	4,691
New Orleans, ...	1,300

Western Port of Canal to San Francisco, ...	2,700
Portland, ...	3,345
Puget Sound, ...	3,458
Valparaiso, ...	2,807
Callao, ...	1,537
Yokohama, ...	7,020

and that the route standing in this attitude before the world, is the one which commends itself as a judicious, economical and prosperous work."

In this connection, the remark of President Hayes, made in his message of March 8, 1880, is pertinent:

"An inter-oceanic canal across the American Isthmus will essentially change the geographical relations between the Atlantic and Pacific Coasts of the United States, and between the United States and the rest of the world. It will be the great ocean thoroughfare between the Atlantic and Pacific shores and virtually a part of the coast line of the United States. Our mere commercial interest in it is greater than that of all other countries, while its relation to our power and our prosperity as a nation, to our means of defence, our unity, peace and safety are matters of paramount importance to the people of the United States."

In a message to the Senate of December 10, 1884, President Arthur transmitted a treaty he had caused to be negotiated with Nicaragua, providing for the assumption by the United States of a permanent protectorate over that country, and for the building, at public expense by our Government, of the Nicaragua Canal. In respect of the work itself and its importance to our country, President Arthur said:

"The establishment of water communication between the Atlantic and Pacific Coasts of the Union is a necessity, the accomplishment of which, however, within the territory of the United States is a physical impossibility. While the enterprise of our citizens has responded to the duty of creating means of speedy transit by rail between the two oceans, these great achievements are inadequate to supply a most important requisite of national union and prosperity. For all maritime purposes the States upon the Pacific are more distant from those upon the Atlantic than if separated by either ocean alone. Europe and Africa are nearer to New York, and Asia is nearer to California than are New York and California to each other by sea. Weeks of steam voyage, or months under sail, are consumed in the passage around the Horn, with the disad-

vantage of traversing tempestuous waters or risking the navigation of the Straits of Magellan. A nation like ours cannot rest satisfied with such a separation of its mutually dependent members. We possess an ocean border of considerably over 10,000 miles on the Atlantic and Gulf of Mexico, and including Alaska, of some 10,000 miles on the Pacific. Within a generation the western coast has developed into an empire with a large and rapidly growing population, with vast but partially developed resources. At the present rate of increase, the end of the century will see us a commonwealth of, perhaps, nearly 100,000,000 inhabitants, of which the West should have a considerably larger and richer proportion than now.

"The political effect of the canal will be to unite closer the States now depending upon railway corporations for all commercial and personal intercourse, and it will not only cheapen the cost of transportation, but will free individuals from the possibility of unjust discriminations."

President Harrison, in his annual message to the Fifty-second Congress, used the following language, which should command the attention of all patriotic citizens of whatever political party:

"I deem it to be a matter of the highest concern to the United States that this canal, connecting the waters of the Atlantic and Pacific Oceans, and giving to us a short water communication between our ports upon those two great seas, should be speedily constructed and at the smallest practicable limit of cost. * * *

"The Senator from Alabama (Mr. Morgan), in his argument upon this subject before the Senate at the last session, did not overestimate the importance of this work when he said that 'the canal is the most important subject now connected with the commercial growth and progress of the United States.' * * *

"I most sincerely hope that neither party nor sectional lines will be drawn upon this great American project, so full of interest to the people of all our States and so influential in its effects upon the prestige and prosperity of our common country."

These are not merely the expressed but the recorded opinions of four of the later Presidents of the United States on a question that has no partisan aspects whatever, and I think we are justified in the belief that the views of the Chief Executive officers of our country reflect the convictions of very large masses of our population.

A Senator, not in political sympathy with the present administration, remarked recently in my presence that he regarded as a great national misfortune the failure of ratification of the Frelinghuysen-Zavala treaty, which it will be remembered had been negotiated during President Arthur's administration.

Thinking men everywhere, regardless of party and section, see plainly the pressing need of convenient means of communication for ships between the oceans washing our shores.

But it is not alone the commercial importance of this work to our country that commends it to the attention of our people. The strategic importance of it has recently been manifested to us.

The strict constructionist of our Constitution finds difficulties in harmonizing the provisions of our Magna Charta with the doctrine of ex-territorial expenditures of the peoples' money, even when a question of national power and defence is involved. The counsel of Washington comes always to mind—that we avoid foreign complications and entangling alliances. But by degrees our people are realizing that our fortunate position, remote from the scenes of strife and contention in the old world, does not exempt us from the rivalries and irritation that often result from commercial intercourse, and efforts to gain new foreign markets and displace the commodities of our rivals in such markets. Great Britain, France, Germany and other manufacturing nations of Europe will not surrender to us willingly their trade in manufactured goods to Japan, China, the East Indies and South America. It is true that for many years we have been unable to actively compete for this trade, but we are making inroads upon it and our manufacturers will soon be in a position to offer such inducements to foreign

buyers as to attract large portions of their traffic to us. The competition resulting will be almost ferocious in character, and happy shall we be if the issue is reached without a trial of military strength.

At present we could neither defend our coasts nor police the oceans effectively. Our enormous wealth, vast portions of it within reach of an enemy's guns, we would be powerless to protect. The conviction by our people of our impotency to preserve our heritage and to protect our citizens abroad, has prompted us to begin the construction of a modern navy and to provide efficient protection for our harbors and foreign commerce. Of our coasts, including Alaska there are 20,000 miles, nearly equally divided between the Atlantic and Pacific, but the length of voyage between our most southern Atlantic port and our most southern Pacific harbor is now more than one-half the circumference of the globe; it is within our power, however, to shorten this to 3,500 miles.

Imagine the military situation under existing conditions in the event of war with any one of the great maritime powers, and let us suppose that all vessels now building and authorized are completed, and the equal in their class of any other navy. In ships and guns we would not possess in the aggregate a number exceeding those assailing us in any one of the three or four fleets that could be mustered by some of the great naval powers of Europe, and our dispositions would of necessity be made for defence only. The enemy would have a fleet on the coast of Japan or China, another near the Cape of Good Hope, and a third near Gibraltar or the Western Islands. Should we wish to transfer any of our vessels from east to west or *vice versa*—a voyage of 12,519 miles is required via the Straits of Magellan between San Diego and Key West. Before our vessels could reach the equator the enemy from Gibraltar could intercept us at Cape St. Roque and the force from Good Hope would be awaiting us at the Straits; or before an American squadron could reach San Diego the hostile ships from China would have anticipated us. How different would be the military situation if we possessed an

isthmian passage, properly fortified, as it would have been under the Frelinghuysen-Zavala treaty!

We are now in the midst of an international controversy of great gravity with one of the nations of South America. The situation is critical in the extreme, and the columns of our daily papers are filled with accounts of hurried naval preparations looking to the enforcement of our demands for reparation. While our force available might be adequate to the execution of the national will, the ships in the Atlantic Ocean can only reach the coast of Chile by way of the Straits of Magellan, and this involves a voyage 3,426 miles longer than would be required if the canal were open and available now. Besides, our country does not possess a coaling station anywhere on or near the existing route, therefore coal for steaming and all other supplies for a fleet operating in the region referred to would have to be forwarded from our own ports. Were the canal open, our depot, in fact, our naval and military base, would be in Nicaragua, but 2,800 miles from the scene of possible conflict, instead of 8,440 miles, as it is now from New York, and about 5,120 miles from San Francisco.

In the great interior lake on the canal line—a body of water one-third as extensive as Lake Erie—would be a marine establishment whence our vessels could dash out upon either ocean and engage the enemy. One "lake" squadron uniting with another from the Gulf of Mexico, could encounter an enemy's fleet among the Caribbees, and returning to the lake to refit could form a junction with our California vessels off the Mexican coast and there contend for mastery with its opponent, all within two weeks of our first action.

The Secretary of the Navy very happily gave expression to the strategic value of an isthmian channel, when he said that the control of such a passage doubled our power for offence and defence, for every one of our ships and guns would be as effective as two of the enemy's.

I cannot detain you with further illustrations, but feel I may venture a single quotation bearing upon this national aspect of the question.

The writer is Captain H. C. Taylor, of our Navy, who certainly has done as much as any other man in bringing this work to public attention: "It is the lake that gives to this route a political and international importance unique and significant. The nation that controls this canal under terms of amity with Nicaragua will here find rest and refreshment for its fleets. Here may the delays of warlike complications, so injurious in sea-water to the iron-hulled frigates of our time, so fatal to their speed, be safely endured without loss of efficiency; the crews growing healthier, the ships more clean-limbed and speedier, in this great fresh water sea. Hence may issue squadrons in the height of vigor and discipline, striking rapid and effective blows in both oceans, and returning to refit in this sheltered stronghold, and to draw from it nourishment and fresh strength for a renewal of hostilities. There cannot be imagined a more potent factor in deciding threatened difficulties or in securing an honorable peace with a powerful enemy, than the presence in this healthy and capacious water fortress of a strong fleet, prepared, at a telegraphic sign from the home government, to issue fully equipped from either entrance for instant service in the Atlantic or Pacific. So vast would be the power of the nation that controlled this transit, and so strong the international jealousies thus created, that it may be considered fortunate that this enterprise should now be moving forward as a purely commercial project, independent of the aid of any government."

NOTES ON THE BLAST FURNACE.

By John Hartman.

[*A lecture delivered before the Franklin Institute, February 19, 1892.*]

Mr. Hartman spoke as follows:

Pig Iron.—History tells that about 1,500 to 1,600 years before Christ the Phœnicians taught the Greeks the manufacture and use of iron. After that time Greek history gives some detailed account of it. The Phœnicians, before leaving their original home on the Indian Ocean, practised the art of iron-making, and on migrating to the Land of Canaan, whose hills were well covered with wood and contained iron ore, they made iron and sold it to the neighboring nations.

Tracing its early history back, it is lost in the twilight of fable. The hurling of Hephæstus from Olympia and the working of iron established by that act, when divested of its fiction, will be found to be the falling of an iron meteorite and the use made of it.

The Cretans' claim to the discovery of iron-making is more rational. Mount Ida in Crete was well wooded and had a fine vein of iron ore on its side. Timber left to grow, decay and fall will accumulate to quite a depth. This timber being accidentally fired at the bottom of the mountain by the inhabitants, in burning upwards burns slower, as the smoke and carbonic acid from below prevents the air from getting freely at the fire above to support combustion. This slow combustion favors turning the wood into charcoal, which, covering any pieces of iron ore, they are reduced or deoxidized by contact with solid carbon. As the wood below is burned off, the pure air sweeping up the hot mountain side, is heated by the ground and rocks, and the charcoal over the ore is burned off at a high heat, causing the slag to flow from the reduced iron, leaving the iron remain as a sponge, which is easily hammered into wrought iron. We have here in nature's work the hot blast and the principle of regenerative furnaces.

The Phœnicians, however, being the older nation, must have the honor of first discovery, and to them more than any other nation the world is indebted for metallurgical science and massive structures. How these people could transport and erect the blocks of stone forming their structures is a puzzle to modern engineers, who with their best appliances, can only lift one-fourth of their weight. They used steel tools, as is shown by the grooves in their quarries, and grappling irons were used to handle the blocks, to which the holes in them attest. All ancient iron was made by reducing pure oxides in a shallow charcoal fire, forming a sponge, and then hammering out the slag, a process carried on to this day.

The oldest and finest of all ruins are at Baalbec, Syria. Their columns, seven feet diameter, in three sections of twenty-four feet each were held together by wrought-iron dowels, but these have been dug out by the Turks and Arabs during the Dark Ages to get material for implements of war and agriculture. They replaced a people of superior intelligence by their rugged nature and strength of muscle, but could not make a pound of iron. In all the Egyptian ruins the same destruction is noted. The massive coping stones of the temples were held together with iron clamps, but they have all been dug out and much of the work of these grand old masters has been destroyed by the lazy, arrogant vandals of the Dark Ages.

To make steel, the ancients submitted wrought iron to the cementation process, which is heating the iron in a closed vessel in contact with carbon at a red heat. In this state it absorbs sufficient carbon to harden it and give it steely qualities. This process is carried on in India to-day.

Aristotle gives us a few notes on iron, but Pliny speaks more freely, thus: "Nature, in conformity with her usual benevolence, has limited the power of iron by inflicting upon it the punishment of rust, and thus displays her usual foresight in rendering nothing in existence more perishable than the substance which brings the greatest danger upon perishable mortality."

He states that the method of making iron is the same as

that employed in making copper, and while some ores produce a metal that is soft and nearly akin to lead, others produce a brittle, coppery iron. Also that "it is a remarkable fact that when the ore is fused the metal becomes liquefied like water, and afterwards acquires a spongy, brittle texture." This can be seen to-day in any Catalan forge, where the slag accumulates, and on tapping off runs like water, leaving behind a brittle, spongy mass, which being consolidated by the hammer, becomes soft and tough. The brittleness is overcome by patting the bloom at first with light blows until it is compacted, then striking heavy blows and drawing it into billets. Also that "iron which has been burned in the fire is spoiled, and is useless until it is forged with the hammer;" this refers to the burned part being worked off in scale and sparks, and that "some iron cannot be worked at a red heat, but must be a bright yellow." This is the modern red-short iron. The iron, he says, "that is used for hob nails is soft like lead," which corresponds to our pure neutral iron, made in the Catalan forge.

The earliest record of furnaces for making molten iron (not sponge) show a hole some 15 inches diameter and 3 feet high in a clay bank. This was filled with charcoal and blown with air caught by deflectors and conveyed to the interior through pipes or reeds. After the furnace was warmed up with the burning coal, charges of ore and coal were put in, and after a few hours a lump of molten iron was taken out of the crucible by tearing the crucible open. This iron contained a little combined carbon, and if it had the right quantity, it could be worked into steel at once, or it could be decarbonized and made into wrought iron. The slag formed in these furnaces was silicate of protoxide of iron from the fusion of part of the ore with the gangue. It was tapped off from the furnace when it accumulated too high.

Carbon exists in iron as combined carbon or as graphitic carbon. Combined carbon makes iron steely or hard; graphitic carbon denotes soft iron. After bellows, made of pig or goat skins and operated by the foot or hand were

invented, higher heats could be obtained. This necessitated the use of more refractory material for the furnace, and caused separate structures to be built. The higher heats gave more combined carbon to the iron, which was worked off in another fire. After the Germans began making iron, they built their furnaces or stuckofens higher to economize heat and save charcoal, as they found wood getting scarce. In these higher furnaces the ore and coal collected the ascending heat and returned it to the crucible, increasing its heat and giving them an iron of different character. Part of the carbon was chemically combined and part was mechanically mixed with the grains, giving the iron a dark color and fluidity so that it would run like molten lead. As this iron was difficult to decarbonize, they called it bad or sow iron.

Prior to the thirteenth century, the art of iron founding was unknown, but with the use of higher furnaces a metal was made that was fluid and could be cast, which soon came into use and formed a new branch of the iron business. As the old German furnaces were small, they run the combined carbon iron out in a long groove made in the sand, as the iron was mushy and flowed with difficulty from the furnace. When they used higher furnaces and made iron with graphitic carbon which ran fluid, they ran short grooves at right angles to the long groove, and filling them with metal, they called them pigs, a practice in use to-day.

By some it is thought the head of the battering-ram used by the ancients was cast iron, but it is too brittle for that purpose; it was forged to the shape shown on ancient monuments. Only rich, pure ores could be used by the ancients. They could not get the intensity of heat in their furnaces to give them graphitic carbon in the iron; hence, they could only make wrought iron.

Among the earliest appliances of cast iron in founding was to make cannon, but they frequently burst in the third or fourth round and killed as many friends as enemies, like some of the canonical laws made at times in the world's progress.

After the iron business had been conducted in England

for many years, the wood becoming scarce, they turned their attention to mineral fuel or coal with more or less success. About 1630 Dud Dudley experimented with coke.

In 1735, Abraham Darbey, of England, made the first successful blast with coke, and from that day to this it has been continued in making pig iron.

In 1837, anthracite came into use for pig iron making in Wales, and is continued in Pennsylvania to the present time.

In 1828, Neilson first applied heated air to the furnace, which raised the temperature of the crucible and allowed a more basic or limy flux to be used. This melts at a high temperature, but picks up the sulphur in the ore and fuel and gives a better iron. With the introduction of hot air, cheaper ores, but containing a higher percentage of sulphur and silica, could be used, which lowered the cost.

The heat of the crucible has been further increased by the use of regenerative stoves giving lower fuel consumption, more output and better iron, as the less fuel used, the less impurity goes from the fuel to the iron.

While metals as a rule increase in value with their purity, pure iron has no commercial existence and is never known outside of the chemical laboratory. Its value is only established when it is combined with carbon, but some of the following elements always accompany it in greater or less quantities and modify its character: silicon, manganese, magnesium, sulphur, phosphorus and aluminum. In chemical combination with iron there is no exact line of demarcation with these elements. Carbon exists in pig iron in the combined or the graphitic state, or in both states. Combined carbon closes the grain of iron, making it smaller and harder. Graphitic carbon is the combined carbon changed by high heat to the graphitic state which softens the iron. Silicon destroys the grain of the iron, making it weaker, softer, and cold-short. Manganese destroys the grain, weakens it and makes it red-short. Magnesium is claimed to soften and strengthen iron. Phosphorus is an unwelcome ingredient which cannot be eliminated and has to be tolerated; it weakens iron and makes it cold-short. Sulphur is

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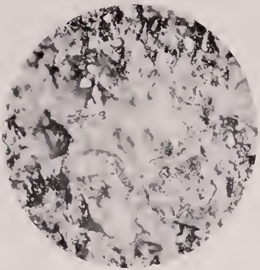


FIG. 1.

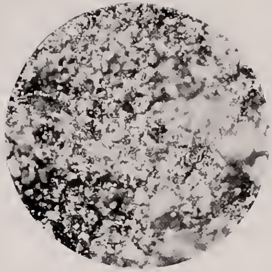


FIG. 2.

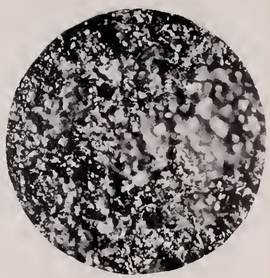


FIG. 3.

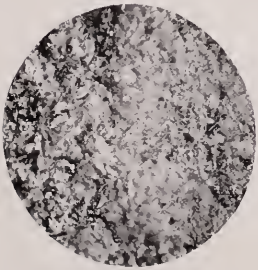


FIG. 4.

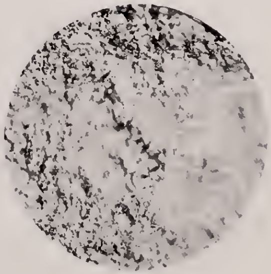


FIG. 5.

FIG. 6.

STANDARD COMMERCIAL GRADES OF PIG IRON.—(See pages 138–139.)

a vigilant enemy, closing the grain, making it harder, and causing red-shortness, but it can be eliminated. Aluminum strengthens and softens iron. Copper makes iron red-short. Cold-short iron will work in the smith's fire at a low heat, but is weak when cold. Red-short iron will work only at a high heat, but is strong when cold. If the iron is not worked at the heat to suit its nature it will crumble or break.

Pig iron is sold in the market in five grades, Nos. 1, 2, 3, 4 and 5. Besides these there are special grades established recently but used extensively, namely: Low phosphorous and sulphur iron used in the open hearth and Bessemer processes, and low silicon with high phosphorous iron, used in the basic process. Silicized iron containing four per cent. to seven per cent. of silicon is also made to soften other irons and make them run liquid.

ANALYSIS OF A STANDARD NO. 1 PIG IRON.

	Per Cent.
Iron,	92·37
Graphitic carbon,	3·52
Combined carbon,	·13
Silicon,	2·44
Phosphorus,	1·25
Sulphur,	·02
Manganese,	·28

Gray.—A large, dark, open-grain iron, softest of all the numbers and used exclusively in the foundry. Tensile strength, low. Elastic limit, low. Fracture, rough. Turns soft and tough.

NO. 2 PIG IRON.

	Per Cent.
Iron,	92·31
Graphitic carbon,	2·99
Combined carbon,	·37
Silicon,	2·52
Phosphorus,	1·08
Sulphur,	·02
Manganese,	·72

Gray.—A mixed large and small dark grain, harder than No. 1 iron, and used exclusively in the foundry. Tensile strength and elastic limit higher than No. 1. Fracture, less rough than No. 1. Turns harder, less tough and more brittle than No. 1.

NO. 3 PIG IRON.

	Per Cent.
Iron,	94·66
Graphitic carbon,	2·50
Combined carbon,	1·52
Silicon,	·72
Phosphorus,	·26
Sulphur,	trace
Manganese,	·34

Gray.—Small, gray, close grain, harder than No. 2 iron, used either in the rolling mill or foundry. Tensile strength and elastic limit higher than No. 2. Turns harder, less tough and more brittle than No. 2.

NO. 4 PIG IRON.

	Per Cent. A.	Per Cent. B.	
Iron,	94 48	94·08	*Mottled.*—White background, dotted closely with small black spots of graphitic carbon, little or no grain. Used exclusively in the rolling mill. Tensile strength and elastic limit lower than No. 3. Turns with difficulty, less tough and more brittle than No. 3.
Graphitic carbon,	2 02	2 02	
Combined carbon,	1 98	1 43	
Silicon,	·56	·92	
Phosphorus,	·19	·04	
Sulphur,	·08	·04	
Manganese,	·67	2 02	

[The manganese in this (*B*) pig iron replaces part of the combined carbon, making the iron harder, and closing the grain, notwithstanding the lower combined carbon.]

NO. 5 PIG IRON.

	Per Cent.	
Iron,	94 68	*White.*—Smooth, white fracture, no grain, used exclusively in the rolling mill. Tensile strength and elastic limit much lower than No. 4. Too hard to turn and more brittle than No. 4.
Combined carbon,	3 83	
Silicon,	·41	
Phosphorus,	04	
Sulphur,	·02	
Manganese,	·98	

Fig. 1, of the plate, shows the fracture of a No. 1 pig of the Thomas Iron Company (as are all the others). The large patches show the grain of the iron, which is rough and projects up in sharp points. On examining it with a powerful glass the grains of iron are found embedded in the graphitic carbon similar to a wall of rubble masonry laid solid in mortar. The grains are connected but the interstices are filled with the graphite. Graphitic carbon high, combined carbon low.

Fig. 2, of the plate, shows the fracture of a No. 2 pig. The patches are smaller, showing a smaller grain. Graphitic carbon lower, and combined carbon higher than No. 1.

Fig. 3, of the plate, shows fracture of No. 3 pig. The patches are smaller than No. 2 and show smaller grain. Graphitic carbon lower, and combined carbon higher than No. 2.

Fig. 4, of the plate, shows fracture of No. 4 pig. The patches are smaller and more of them than in No. 3 and

show little or no grain. Graphitic carbon lower and combined carbon higher than No. 3.

Fig. 5, of the plate, shows fracture of No. 5 pig. The patches are small and closer but no grain. No graphitic carbon, all combined carbon.

The strength for tension culminates in No. 3 pig iron, but falls off more rapidly from No. 3 to No. 5 than from No. 3 to No. 1.

	Per Cent. Combined Carbon.
Malleable iron contains	·25
Steely iron contains	·35
Steel contains	·50
Hard steel contains	1 to 1·50

Taking the sum of the graphitic and combined carbon in each quality of pig iron they are practically the same. The softness of pig iron is dependent on the amount of graphitic carbon in it. Separating the iron in the No. 1 pig from the graphitic carbon, it is a nearly pure wrought iron embedded in the graphitic carbon, and it is the absence of combined carbon which gives it the softness and flexibility that make it desirable for machinery and other purposes.

The grains of iron are crude crystals. When the iron is nearly pure and allowed to cool very slowly, regular octahedral crystals of iron are formed. Fine crystals were found twelve years ago in the hearth of Crown Point Furnace. They used an ore low in phosphorus, sulphur and manganese. These crystals are now in the Academy of Natural Sciences.

No. 1 pig iron may be defined as being composed of grains of wrought iron connected together but embedded in graphite. No. 2 pig iron has more combined carbon, which converts the wrought iron into a soft steel harder to the tool working it. No. 3 pig iron has more combined carbon, and the iron portion is a crude steel harder to the tool working it. Nos. 4 and 5 are virtually crude, high combined-carbon, steels.

The numbers here given, 1, 2, 3, 4, 5, for qualities of pig iron are the old standard. Some founders grade in

given. If the impurities in pig iron were uniform, which would be the case if there were only one kind of ore and fuel, the proper plan would be to buy iron by chemical analyses on a basis of graphitic and combined carbon, but the impurities so change the character that the eye is found to be the best guide so far in fixing the grade. In running the ends of the fingers over the fracture of a pig of iron, if the ends of the grain tear the fingers, the iron is strong. The analysis (B) of No. 4 pig iron, shows low in combined carbon, but the manganese hardens the iron and changes it from gray to mottled iron.

Fig. 6, of the plate, is a hot-blast No. 1 charcoal iron from Grand Rivers, Ky. The pigs bend before breaking. The ends of the grain are sharp and tear the fingers. The analysis is as follows:

	Per Cent.
Silicon,	1·955
Sulphur,	·029
Phosphorus,	·488
Manganese,	·213
Graphitic carbon,	3·310
Combined carbon,	·460
Iron,	93·545

On breaking this iron, the pig when it strikes the breaking blocks, emits a dull thud like lead. It is an iron of high tensile strength and well adapted for making car wheels. There are times in furnace practice when the first iron at a cast runs sluggish and mushy, but the iron on cooling is found to be excellent No. 1. This iron is the first formed directly after casting and lying near the tapping hole has slowly lowered its temperature and formed coarse grained iron. On opening the tapping hole the more fluid iron in the hearth pushes this cooler iron out first and it is then followed by the fluid iron.

The bending of pigs is not confined to charcoal iron. Coke and anthracite iron do the same when using good stock and running the furnace at the proper temperature.

Referring to the pig iron furnace section, *Fig. 7*, the air blown through the tuyere is quickly converted to carbonic oxide gas and the heat from it keeps the fuel in the bosh at

a white heat. The bosh and hearth are always filled with fuel when the furnace is working well. If the heat in the bosh becomes too high from a light burden, the silicon in the fuel is reduced, part of it going to the pig iron, giving a weak, light iron. When silicon is reduced, the cinder will

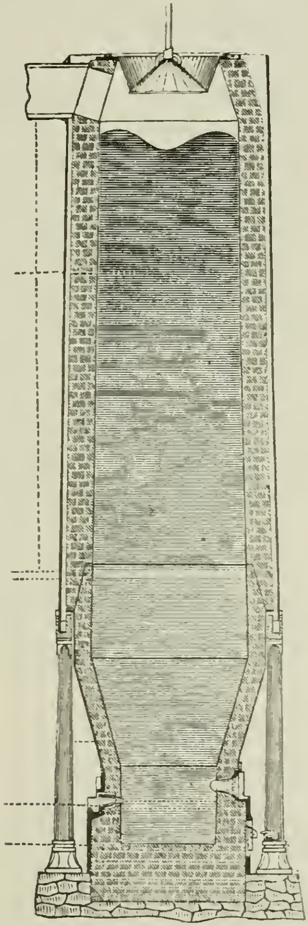


FIG. 1.

not take it up, what escapes the iron is burned to silica in the stoves and boilers; hence the heavy white fumes at the chimney top. Silicized iron was unknown to the ancients for want of heat to produce it. With a good burden of ore the heat of the bosh can be kept at the temperature

six divisions, and in some cases ten to eleven grades are required for a given iron. As the ore reduces in the upper part of the furnace a finely divided carbon penetrates the ore and combines with the iron; when the iron melts out of the ore it leaves it with the carbon in the combined state. As it trickles down through the glowing fuel it may form some graphitic carbon, but as a rule, it reaches the crucible with combined carbon only. With a clean, hot hearth, the carbon in the iron is gradually transformed to graphitic carbon. As the fluid iron running from the furnace cools, more or less of the carbon separates as graphitic carbon which is squeezed into the interstices between the grains as they form. If this pig iron is run against a cold plate the graphitic carbon is changed to combined carbon, and the lower the silicon in the pig iron the harder and greater is the depth of the change. If the thickness of the running iron is too great to change the whole thickness of the pig iron, then part of the pig will be close and hard, while the other part is open and soft. As more burden of ore is applied to the furnace the heat of the bosh and crucible is decreased, and Nos. 2, 3, 4 or 5 is produced as the bosh and hearth get cooler.

In making No. 1 iron, the founder must be careful to keep a large, clean, hot crucible, as the finishing touches to the iron for grade are made in it. In the crucible alone and not above it, must the intensity of the heat be applied to the iron to form graphite.

After the founder has made good No. 1 pig, it is sent to market and bought for the cupola. The cupola is charged with fuel and iron, the No. 1 iron being placed in the lower part of the cupola on a good bed of fuel, above it is more fuel, and on this is laid the harder iron. Suppose it is to make a roll; then No. 3 would be used. Blast is applied to the cupola, it burns up one side more than the other, and the hard iron above melts, comes down and mixes with the good No. 1 meant for pulleys; the result is, both irons are spoiled, and the founder making the No. 1 gets soundly berated for making an iron that changes in remelting.

Again, suppose all No. 1 is charged, and the iron is

melted at a lower temperature than that at which it was made; the carbon will partly change from graphitic to combined carbon, and make the iron harder. Again, suppose the fuel is high in sulphur, the iron, in the absence of the strong basic cinder of the blast furnace will take it up, closing the grain and making the iron harder; or, if the cupola scaffolds on one side, the air rushing up through the contracted opening decarbonizes the shots of falling iron and makes it harder. Iron melted with an excess of fuel will take up the kish or graphite formed by the intense heat, and on pouring the casting the cooling effect of the pouring squeezes out the graphite, which floats to the top of the mould and makes spongy castings. It is important to melt with the proper heat and no excess. Certain sands also exert a bad mechanical influence on pig iron by forming an asbestiform material that floats to the top of the mould, making defective castings.

Iron, to retain its quality as sold, should be melted by gas containing no free air. The gas should be burned to carbonic acid with an excess of air while heating up the iron. As soon as melting begins, the gas should be burned to carbonic acid with a slight amount of carbonic oxide in excess to take care of any truant air entering the furnace door. This can be accomplished by a regenerative furnace, using gas for heating. This furnace is the same as the open hearth furnaces now in use in all our large steel works, and consists of a square building of iron plates, lined with refractory brick and having a basin-shaped hearth on bottom. At each end of the square building are two round iron stoves, filled with fire brick having numerous passages from top to bottom of the bricks, called regenerators. The hearth and regenerators having been warmed up by wood, gas is turned through one of the regenerators and air through the other alongside of it. The gas and air meet at the end of the hearth and burn across it, heating it up and melting the iron placed on the bottom of hearth. After the burned gas passes the hearth, it enters the two opposite regenerators, heating them up. When the two first regenerators begin to cool off, the valves are reversed and the gas

and air sent back over the iron and through the other two regenerators. The burned gas in passing through the two first regenerators heats them up, when another reverse is made, and so on until night. By this arrangement all the waste heat of the furnace is utilized except the heat escaping in the carbonic acid at the chimney, which is about 350°. Comparing this with the 2,000° escaping at the chimney of the cupola, a saving is effected in fuel. It will be safe to take the saving at 100 pounds fuel per ton of iron melted, which will pay the interest on difference of cost between the cupola and open-hearth regenerative plant.

With this furnace, slow or quick melting, and hot or cold melting, can be had at once; no sulphur will be taken up by the iron, and it can be kept at any desired heat, which avoids a change in the original quality. A perfect mixture can be made, as different irons charged when melted can be well stirred through the doors and made homogeneous. No precision of this kind can be obtained with the cupola, as it is guess-work when certain qualities of iron get down to the melting-point, and they cannot be stirred except in the ladle, which may not get equal quantities of each iron. No graphite can be formed in this furnace to make poor castings. An objection to this furnace will be the loss of heat keeping it hot over night with a small volume of gas, but it has the advantage of being ready in the morning for work as soon as the men arrive. As the high heat used in open hearth steel plants is not required for melting pig iron, the loss in heat to keep furnace warm over night would be slight. With the improved cranes and appliances for handling the metal, there is no longer need of suspending all moulding while pouring. When this system is taken up and worked out carefully in all its details, it will prove a decided success, as moulding and pouring can go on side by side.

From the data now being collected by the different iron works, some active brain in the future will give the world a table, showing how each element affects the pig iron, and by it a founder will be enabled to make his mixture to

produce the required results without having recourse to trial for each brand of pig iron.

The blast furnace is still in its infancy, yet in this country it has made rapid strides, and gone far beyond Europe in output and low fuel consumption.

THE PRESENT STATUS OF THE STORAGE BATTERY SYSTEM OF STREET RAILWAY PROPULSION.

BY PEDRO G. SALOM.

[*Read at the stated meeting of the Franklin Institute, held June 15, 1892.*]

JOS. M. WILSON, President, in the chair.

MR. SALOM: A distinguished scientist once told me that many years ago he was invited to give his first public lecture. He chose a subject that he thought he was very familiar with, as it was one in which he had been making long and careful investigations, but much to his amazement, after talking for ten or fifteen minutes, he found that he had exhausted the subject, and had told his audience all that he knew about it. Then he said he began to repeat himself, and he had continued to repeat himself ever since. Personally I am in very much the same position. I feel that I have already told all that I know about storage batteries, except what has been already better told by others. Still an old truth presented in a new light sometimes carries conviction for the first time.

This, then, is my reason for being here this evening. In discussing "The Present Status of the Storage Battery System of Electric Street Railway Propulsion," there are three questions to be considered:

(1) Why is it that so promising a field in electrical engineering has as yet produced no adequate commercial results?

(2) What definite knowledge has been gained by the trials and failures of the past? and

(3) What are the prospects for the future for the introduction of storage battery traction?

Now, in respect of the first question, I would say that undoubtedly the dreadful patent-litigation in which the whole subject of storage batteries has been involved is largely responsible for the failures in the past, although there are other causes which I will touch on presently.

I will not burden you with a history of the patent litigation, which has now extended over a period of five years and which has been prosecuted with a degree of vigor and intensity (and I might even say malignity) worthier of a better cause, further than to say, that the fundamental principle upon which all forms of storage batteries are constructed has been thrice awarded to Chas. F. Brush in the lower courts, and the case is now before the court of last resort, whose decision may be expected at any time, and which, of course, will be final. The fundamental principle just referred to is the broad claim for the application of the active material to a conducting support.

This uncertainty, therefore, of the ownership of the basic patents has rendered capital timid. Conservative street car companies could not afford to equip their lines with a system that might be adjudged an infringement of others' patents, and upon which an injunction might issue at any time, and on the other hand the battery companies have not been in a strong enough financial position to properly equip and operate a line of sufficient magnitude to demonstrate the practicability and commercial success of their respective systems, or at all events if they have been, they have utterly failed to do so.

I might add, also, that as a further result of this doubt or uncertainty as to the ownership of the patents, a large number of storage battery companies have sprung up in all parts of the country without any possible reason for their existence beyond the fact that their promoters thought that it was only necessary to change the shape or form of a

plate to escape the patents and for the further purpose of selling stock to the innocent public.

Many of these attempts show an utter ignorance and disregard of all the principles that are well known on the subject.

Thousands, yes, hundreds of thousands of dollars have been squandered in this way, much to the sorrow and disappointment of the many innocent stockholders, and to the dismay and confounding of the general public, who, seeing so many failures, have come at last to doubt the practicability, or even possibility, of a commercial battery. We, however, have nothing to do with this. The success or failure of an engineering problem, fortunately, does not depend upon what the general public may think about it, unless it be a problem requiring an enormous capital, which can only be obtained through the Government or by the coöperation of a large number of individuals. What, then, does it depend on? It depends on our ability to demonstrate that we can accomplish a desired result in a better and cheaper way than has heretofore been employed.

This brings us, then, to our second query.

What definite knowledge has been gained by the trials and failures of the past?

This, of course, is a vast subject of inquiry, as it embraces our entire experience during the past six years, and my time will only permit me to dwell on the essential features.

Assuming, now, for the sake of argument, that electric storage traction is practicable, what are the problems that confront the engineer?

The first and most important is the life of the battery.

(2) The capacity.

(3) The rate of discharge.

(4) The weight and size of the elements.

(5) The loss of power in the various transmissions between the prime mover and the axle; or, in other words, the relative efficiency compared with other methods.

(6) The distance or total length of line.

(7) The grades and curves.

(8) The speed.

We will not consider all these points separately, but the whole question in a general way.

In traction work there is only one reliable method of determining the life of the battery, and that is on the basis of car mileage. It is all nonsense to talk about batteries lasting eight months or eighteen months, unless there is a record at the same time of the amount of work accomplished, measured in electrical horse-power hours. The highest record yet obtained, that I have any reliable knowledge of, is that of a single set of 108 accumulators making over 6,000 miles. This record was made on the Citizen's Passenger Railway, in Indianapolis, and was made under the most trying and unfavorable circumstances.

Assuming that the battery could make 100 miles per day, this would mean that the battery would have to be renewed every sixty days. If fifty miles per day, then the life would cover a period of four months; and at twenty-five miles per day, eight months, etc. So you can readily understand that the bare statement that a battery would last six or eight months does not convey a correct idea of the real life of the battery.

Let us see what it would cost to run 6,000 miles with a single set of accumulators, or since two sets are always employed, the one being charged while the other is in service, we will make the calculation on a basis of 12,000 miles.

216 positive groups, at $2.50,	=	$540 00
Credit 2,592 pounds lead scrap at 3 cents	=	77 76
Balance,		$462 24

$462{\cdot}24 \div 12{,}000 = 3{\cdot}85$ cents per car mile.

What amount of work is represented by this 6,000 miles, so far as the accumulators are concerned?

It was found by keeping the most careful records on the Fourth Avenue Line in New York, that the amount of energy consumed per car mile was about one and one-half E. H. P. hours. That is to say, that after making a round trip of eleven and one-half miles, it required about seven-

teen E. H. P. hours to replace the energy drawn from the batteries. Six thousand miles would, therefore, require 9,000 E. H. P. hours, and since a battery of 108 cells has a capacity of fifty-four E. H. P. hours for each total discharge, if we divide 9,000 × 54 we get 166 discharges that are required of the battery, before the positive plates break down. Any one who has had any extensive experience with storage batteries knows that this is a very conservative estimate of the amount of work that a good battery will perform.

It may be asked, have there been no improvements in late years with a view of diminishing the number and weight of batteries required to propel a car? I regret to have to answer, no, and this brings me to the consideration of the limitations of storage batteries.

I have said that it requires about one and one-half E. H. P. hours per car mile, and that 108 accumulators are used and necessary for a twelve-mile run, and they have a capacity of fifty-four E. H. P. hours, or three round trips.

Why is it not possible to use a battery with one-third the weight? Simply because the weight of battery required is not according to the total amount of work to be done, but according to the rate at which it is to be done.

Let us go back to our twelve-mile run again. This requires one and one-half E. H. P. hours per car mile, or, 1,119 watt hours, and since the E. M. F. is about 225 volts, this would be equivalent to nearly five ampère hours per mile, or sixty ampère hours for the round trip; and since the trip consumes two hours' time, this is an average rate of discharge of thirty ampères all the time.

Of course, it is very much greater than this at times, when the car starts or is going up steep grades, etc., when the battery is frequently called upon for a rate of discharge of over 100 ampères.

Now, if we were to use a smaller battery of less total capacity, there would not be sufficient surface area of active material exposed to develop such a current, the E. M. F. would drop and the car stop running. This is the trouble with all thick plate batteries. The amount of surface area exposed is comparatively small for the weight of battery.

A reference to the following diagram, showing the curves of discharge (at 100 ampères) of four types of accumulator, will illustrate very forcibly why thick plate batteries are not available for traction purposes.

The first two curves are from thin plate batteries, and the second two from thick plate batteries, all tested under the same conditions.

This comparison is not intended as a disparagement of the thick plate batteries, the Donaldson-Macrae type in particular having a number of very valuable features embodied in its construction, but it is only designed and intended for compartively low rates of discharge.

It will be observed that in the thick plate batteries that the E. M. F. falls in one case to 1·5 volts in twenty-three minutes, while in the second case, although it falls more rapidly at first than the former, it maintained the current ten minutes longer before a fall to 1 5 volts was reached.

When the E. M. F. falls below two volts per cell the efficiency of the motor begins to fall *pari passu*.

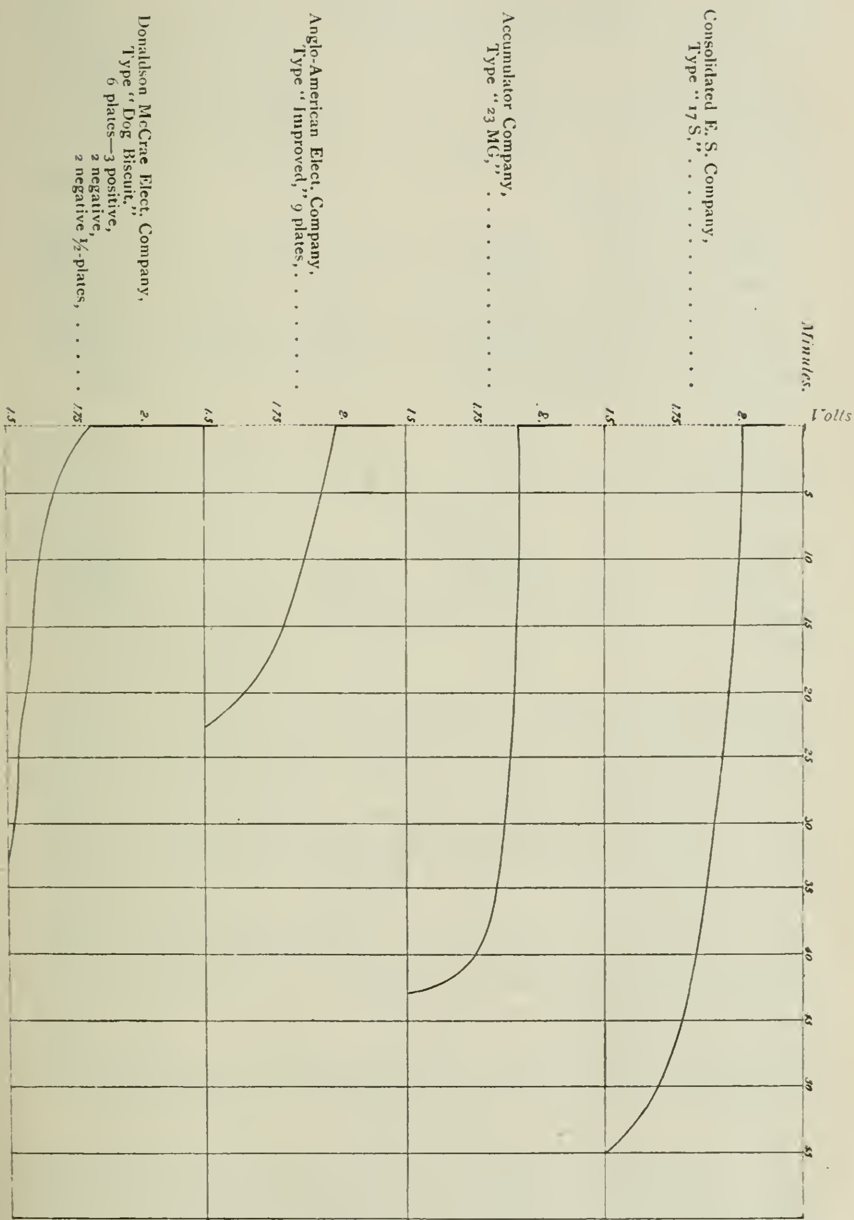
Finally, we come to the consideration of the prospects for the future of storage traction.

It seems to me, in view of the facts which I have just stated, and which are indisputable, that the introduction of storage traction for surface roads in our large cities is inevitable.

The trolley may be introduced at the present time, pending the solution of the difficulties under which storage batteries have come into disrepute, but that it can obtain in the long run against the many and obvious advantages of the storage system is incredible. Let the public once understand that there are no insurmountable difficulties connected with the storage system, beyond the fact that it costs a few cents more per car mile than the trolley, and the demand for its introduction will be irresistible.

The public are not interested in the cheapest and most objectionable method of transit, especially where they derive no benefit from the economies effected, but they are interested in and entitled to a safe, reliable and absolutely unobjectionable method of transit, which is cheaper than

DISCHARGE OF ACCUMULATORS AT 100 AMPÈRES (RATE MAINTAINED).



horses at the present time, and which may in a few years, from the further knowledge and experience gained by actual use, almost, if not quite, compete in cost with the trolley.

The reports of the West End Road in Boston for the months of May and June, 1891, show that the total cost of the overhead system was about twenty-one cents per car mile, while that of the horse system was about twenty-five cents per car mile.

These reports, showing the net results of the actual working conditions on a very extensive scale, are far more accurate than any paper calculations based on theoretical and ideal conditions, as all the uncertainties and unknown quantities always arising in actual operations are included in these results.

Now, inasmuch as nearly all the electrical and mechanical conditions are constant in both the trolley and storage systems, with the exception of the overhead line and batteries (with some minor advantages favoring the storage system,) if we can show that the additional cost of the batteries, over and above the entire cost of the trolley system, does not exceed four or five cents per car mile, then it is manifest that the storage system will supersede the horse system, as the collateral advantages are so great as to render the consideration of any other system out of the question.

This, I think, we have already demonstrated by the record of the Indianapolis battery given above, and which is confirmed by the report of the Birmingham Central Tramway Company, Limited, wherein it is shown conclusively that with only a small installation of five or six cars, it is cheaper to run with storage batteries than with horses. I append below the results obtained at Birmingham with horse and storage battery traction.

COMPARISON OF COST OF OPERATING PER CAR MILE WITH HORSES AND STORAGE BATTERIES AT BIRMINGHAM, ENGLAND.*

The number of miles made by the storage battery cars, from July 24, 1890, to June 30, 1891, was 138,396, and they

* *Electric Review* (English), August 14, 1892.

carried 1,144,718 passengers. If five cars were in service, this would make nearly 28,000 miles per car.

The gross revenue was	£8,732
The gross expenditures,	5,711
Balance	£3,021

STORAGE BATTERY TRACTION.

	Pence.	
Electric Haulage.		
Wages,	2·6	
Fuel,	1·66	
Stores,	·73	
Water and lighting,	·07	
Sundries,	·09	
		5·15
Machinery.		
Material,	·29	·29
Car Repairs.		
Wages,	·6	
Material,	1·33	
		1·93
Total traction expenses,		7·37

HORSE TRACTION.

	Pence.	
Wages,	2·44	
Forage and bedding,	3·72	
Veterinary and shoeing,	·40	
Water and gas,	·06	
Harness repairs,	·16	
Stable utensils,	·04	
Sundries,	·08	
Renewals,	·43	
		7·33
Repairs.		
Wages,	·28	
Material,	·26	
		·54
Total,		7·87

From which it appears that the total cost for storage battery traction was 7·37 pence or 14·74 cents per car mile, and for horse traction was 7·87 pence or 15·74 cents per car mile, and I would call special attention to the fact that, under the heading car repairs, the item of material is only 1·33 pence, or 2·66 cents per car mile, and assuming that this was all for renewals of battery (although, of course, some of the expense must have been for repairs to motors, etc.), we find that the cost of battery renewals (really the only unknown quantity in this problem), was only 2·66 cents per car mile. In view of such facts, is it possible to contend any longer that storage battery traction is not commercial?

I have purposely refrained from discussing the subject except from the one point of view—the storage battery. Every one knows that electric traction is a brilliant and phenomenal success and in advocating the storage system, we are merely proposing to furnish current to the motors,

indirectly by means of a battery instead of directly through a central station.

Of course, the same problems obtain in regard to gearing and motors, etc., in both systems and do not enter into the question as propounded.

In my judgment the storage battery has a future. You cannot pound the life out of a fact. All the slander and ridicule that has been heaped upon storage batteries does not alter their capacity to do a certain amount of work at a given cost, one ampère second.

Give the storage battery a chance. Let the same engineering skill and ability be applied to the storage system as has already been done with the trolley, and the results will be surprising.

ON THE SPECIFIC HEAT OF BRINES OF DIFFERENT SPECIFIC GRAVITY.*

BY DR. HANS VON STROMBECK.

[*Read by title.*]

If in refrigerating plants the cooling effect is not done directly by the evaporation of the liquid, almost always brine, a solution of sodium chloride (salt) in water is used for transmitting the cold generated in the expansion coils to the place where the cooling effect is wanted. In order to be able to calculate the quantity of a brine of a certain concentration which is required for transmitting the cold generated, the specific heat of the brine must be known. Since the exact values for the specific heat of brines of different specific gravities were not yet known, I determined them by a series of tests. The results showed that the figures obtained from the tests for a certain brine differs more or less from, but is always less than, the figures we obtain by calculating the specific heat of the same brine from its contents of water and sodium chloride.

* From the Laboratory of the De La Vergne Refrigerating Machine Co.

In the following table I give the figures obtained from the tests:

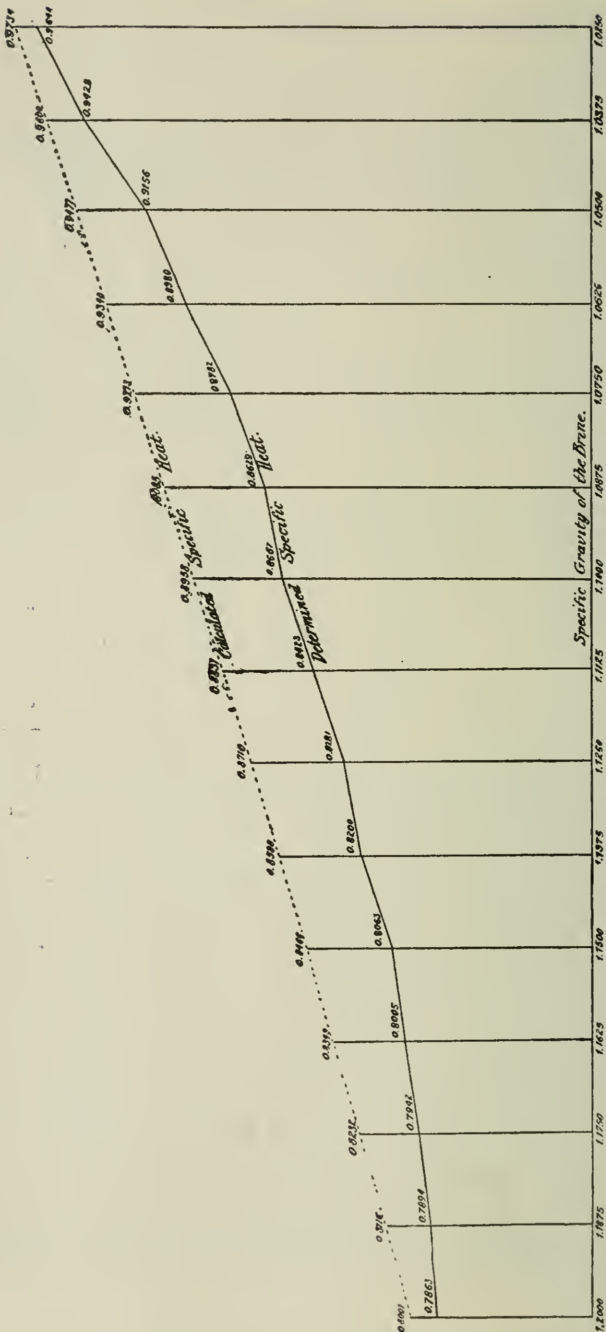
Specific Gravity of the Brine at 60° F.	The Figures in the Preceding Column being its Specific Gravity, the Brine contains Per Cent. of Salt.	Specific Heat of the Brine Calculated from its Contents of Water and Salt, the Specific Heat of the Latter taken to be 0·228.	Determined Specific Heat of the Brine, each Figure being the Average of Four Determinations well agreeing with one another.
1·0250	3·4496	0·9734	0·96440
1·0375	5·1698	0·9600	0·94284
1·0500	6·8547	0·9471	0·91561
1·0625	8·5377	0·9340	0·89798
1·0750	10·2165	0·9213	0·87819
1·0875	11·8569	0·9085	0·86295
1·1000	13·4960	0·8958	0·85610
1·1125	15·1313	0·8831	0·84233
1·1250	16·7096	0·8710	0·82810
1·1375	18·2864	0·8588	0·81998
1·1500	19·8649	0·8466	0·80631
1·1625	21·3871	0·8349	0·80050
1·1750	22·9030	0·8232	0·79417
1·1875	24·4199	0·8116	0·78936
1·2000	25·8884	0·8001	0 78633

From the graphic representation, it can still better be seen how the specific heats, calculated and determined, differ in a different degree from one another.

The tests were made in the following manner:

The apparatus* (see *Fig. 1*), which I think was first designed by Regnault, is made of brass. Tank *A B C D* is filled to such an extent with water that the end *a* of pipe *a b* dips into the water about one inch. By means of the burners *B′ B″* the water in *A B C D* is kept boiling. The steam developed escapes through the pipes *F B* and *E G*, and circulates in the drum *F H I K*. In order to lessen the cooling influence of the air and the loss of heat by radiation, the drum is surrounded by a lagging, the tank and the

* I used this apparatus also for the determination of the specific heat of liquid ammonia (vol. cxxx, No. 780, of this journal) after I had made some alterations.



Graphic representation of the specific heat of brines of different specific gravity.

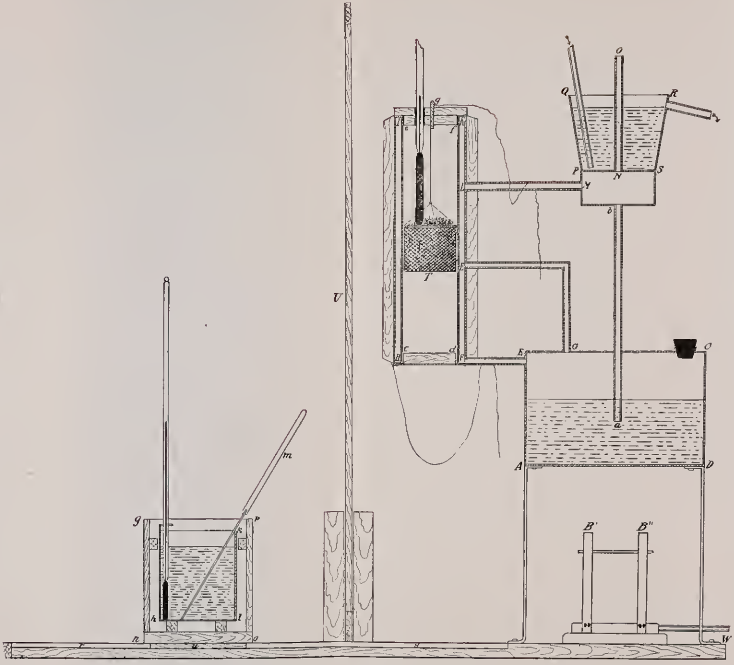


FIG. 1.—Sectional view of the apparatus.

pipes are polished as brightly as possible. One portion of the steam developed in $A\ B\ C\ D$ while passing the pipes and circulating in the drum is condensed and flows back to tank $A\ B\ C\ D$; another portion escapes through pipe $L\ M\ N\ O$. Pipe $L\ M$ is enlarged into a box, into the bottom of which pipe $a\ b$ empties, the top of it being connected with pipe $N\ O$. Pipe $N\ O$ is surrounded by box $P\ Q\ R\ S$. This box is always kept filled with cold water from the hydrant which supplies the same at the bottom of the box, the warm water flowing out at the top. Thus the steam, while escaping through $L\ M\ N\ O$ is condensed and through the pipe $a\ b$ trickles down into tank $A\ B\ C\ D$, where it is transformed into steam again. By this arrangement steam can be developed by the same quantity of water for days without its needing to be renewed. The brass-wire basket T filled with brass tacks, the weight of which, both together, is known, is suspended in the middle of the cylinder $c\ d\ e\ f$ by means of a silk thread and the plug g. The top of the cylinder is closed by the cover $e\ f$, which is tightened by a rubber ring, the bottom by the lid $c\ d$, which is covered on the inside by a wooden plate. It can be opened and closed by means of a thread, hook and hinges. The thermometer going through the cover, and also being tightened by a rubber ring, reaches to the top of the brass basket. The dimensions of the thermometer are taken in such a way that $0°{\cdot}01$ can be estimated, and that the column of mercury, when indicating the highest temperature which can be produced in $c\ d\ e\ f$ only projects a little over the cover. Thus the temperature prevailing in the cylinder can directly be read on the thermometer, and no correction is necessary. The wooden partition U, which is intended to keep away from the calorimeter $h\ i\ k\ l$, any influence of the heat caused by the burners $B'\ B''$, can be moved forwards and backwards between two posts.

The brass calorimeter $h\ i\ k\ l$, the weight of which is known, is filled with a weighed quantity of the brine, the specific heat of which is to be determined. It is provided with a thermometer, and the agitator m, by means of which the temperature of the brine is equalized in all parts.

The dimensions of the former again are taken in such a way that $0^{\circ}.01$ can be estimated, and that the column of mercury, when indicating the temperature of the brine in the beginning of the test, does not project much over the surface of the same. Calorimeter *h i k l* is put in the wooden box *n o p q*. The board *V W*, which supports the whole apparatus, has the groove *r s* in its longitudinal extension. Box *n o p q* having at its bottom the projecting board *u* fitting groove *r s*, can easily be made to slide forward and backward under the cylinder *c d e f*, after partition *U* has been moved backwards. After the apparatus is properly adjusted, the burner $B_{\prime}$ $B_{\prime\prime}$ are lit. When the thermometer in *c d e f* indicates a constant temperature, the temperatures indicated by each thermometer and the time are noted down, partition *U* is moved backwards, lid *c d* swung open, box *n o p q* slid under cylinder *c d e f*, basket *T* lowered into calorimeter *h i k l*, box *n o p q* slid back, partition *U* removed into its previous place, and the ascension of the thermometer in the calorimeter *h i k l* is watched. As soon as it begins to go down, the time is noted down again, thus giving us the number of seconds during which the thermometer ascended. From the moment it begins to descend, during some minutes the temperatures indicated by the thermometer every sixty seconds are noted down. From the figures thus obtained, the specific heat of the brine can be calculated.

Further below, I give the four authentic proofs for the determination of the specific heat of brine of 1·1875 specific gravity. In the following I shall add to each item the figures obtained from the third of these four tests.

If M means the weight of brass tacks and basket together (446·0 grammes);

σ means the specific heat of brass (0·0939);

m means the weight of the brine filled into the calorimeter *h i k l* (510·0 grammes);

T means the temperature prevailing in cylinder *c d e f* ($95^{\circ}.771$ Cels.);

τ means the temperature of the brine indicated by the thermometer at the beginning of the test ($21^{\circ}.20$);

τ_1 means the temperature of the brine indicated by the thermometer at the end of the test (28°·05);

x means the specific heat of the brine that is to be determined;

we arrive at the following equation:

$$x\,m(\tau_1 - \tau) = \sigma\,M\,(T - \tau_1) \qquad (1)$$

In this equation we did not take into consideration the heat which is absorbed by the brass of the calorimeter *h i k l*, and the thermometer in it for being heated up from τ to τ_1 degrees.

If μ means the weight of the brass calorimeter (75·2 grs.);

μ_2 means the weight of the thermometer in it;

σ_2 means the specific heat of the thermometer, and these values are introduced into equation (1);

we obtain equation

$$x\,m\,(\tau_1 - \tau) + \sigma\,\mu\,(\tau_1 - \tau) + \mu_2\,\sigma_2\,(\tau_1 - \tau) = \sigma\,M\,(T - \tau_1) \qquad (2)$$

$\mu_2\,\sigma_2$ is determined in the following manner: The thermometer is put in warm water, then put in a weighed quantity of cooler water and it is observed what temperature the water has obtained by the bringing in of the thermometer.

If θ means the temperature of the thermometer when put in the water;

ϑ means the temperature of the water before the thermometer was put in;

ϑ_1 means the temperature of the water after the thermometer had been put in;

m_1 means the weight of the water;

we obtain

$$\sigma_2\,\mu_2\,(\theta - \vartheta_1) = m_1\,(\vartheta_1 - \vartheta)$$

or

$$\sigma_2\,\mu_2 = \frac{m_1\,(\vartheta_1 - \vartheta)}{\theta - \vartheta_1}$$

The value for $\sigma_2 \mu_2$ is the same in all tests. The observations having been:

θ, ...	$= 29^{\circ}\cdot84$	$29^{\circ}\cdot18$	$29^{\circ}\cdot77$	$29^{\circ}\cdot78$
ϑ, ...	$= 20^{\circ}\cdot85$	$20^{\circ}\cdot74$	$20^{\circ}\cdot80$	$20^{\circ}\cdot82$
ϑ_1, ...	$= 23^{\circ}\cdot06$	$22^{\circ}\cdot67$	$22^{\circ}\cdot86$	$22^{\circ}\cdot96$
m_1, ...	$=$ 5·7 grs.	5·7 grs.	5·7 grs.	5·7 grs.
we find $\mu_2 \sigma_2 =$	1·86 grs.	1·67 grs.	1·69 grs.	1·78 grs.

average of $\mu_2 \sigma_2$ . . . . $=$ 1·75 grs. of water.

But we have to make one correction more. In these equations we admitted the difference $\tau_1 - \tau$ to be in reality

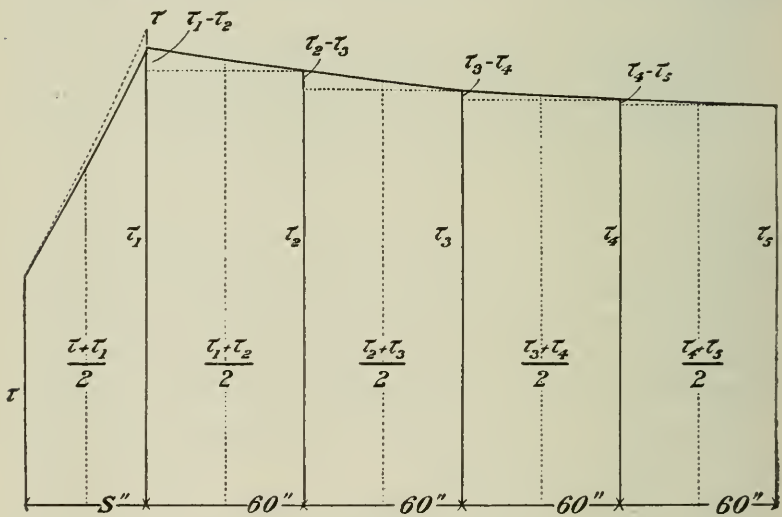


FIG. 2.

all the heat given by the brass tacks and basket to the brine in the calorimeter, to the calorimeter itself and to the thermometer in it. But this supposition is not true, as during the tests the brine, calorimeter and thermometer lost heat by radiation and by the cooling influence of the air. Without this loss of heat the thermometer would not only have gone up to τ_1 degrees (see *Fig. 2*), but a little more, to $\tau_1 + \delta$ degrees. This δ is determined in the following manner:

It took s seconds (45″) to raise the temperature of the brine from τ to τ_1 degrees. Then after having stopped a moment, the thermometer began to go down. It went

down in the first sixty seconds from τ_1 to τ_2, in the next sixty seconds from τ_2 to τ_3, from τ_3 to τ_4, from τ_4 to τ_5, or the decreases were $\tau_1 - \tau_2$, $\tau_2 - \tau_3$, $\tau_3 - \tau_4$, $\tau_4 - \tau_5$, the values

$$\frac{\tau_1 + \tau_2}{2} \qquad \frac{\tau_2 + \tau_3}{2} \qquad \frac{\tau_3 + \tau_4}{2} \qquad \frac{\tau_4 + \tau_5}{2}$$

representing the average temperatures prevailing during each sixty seconds. It is:

$$\tau_1 - \tau_2 = \frac{\tau_1 + \tau_2}{2} \cdot 60 \cdot k_1$$

$$\tau_2 - \tau_3 = \frac{\tau_2 + \tau_3}{2} \cdot 60 \cdot k_2$$

$$\tau_3 - \tau_4 = \frac{\tau_3 + \tau_4}{2} \cdot 60 \cdot k_3$$

$$\tau_4 - \tau_5 = \frac{\tau_4 + \tau_5}{2} \cdot 60 \cdot k_4$$

If we dissolve these equations for k, we obtain

$$k_1 = \frac{2\,(\tau_1 - \tau_2)}{(\tau_1 + \tau_2)\,60}$$

$$k_2 = \frac{2\,(\tau_2 - \tau_3)}{(\tau_2 + \tau_3)\,60}$$

$$k_3 = \frac{2\,(\tau_3 - \tau_4)}{(\tau_3 + \tau_4)\,60}$$

$$k_4 = \frac{2\,(\tau_4 - \tau_5)}{(\tau_4 + \tau_5)\,60}$$

and by taking the average of $k_1\ k_2\ k_3\ k_4$, the value of k, *i. e.*, of a coëfficient, which multiplied by the number of seconds which the test lasted, and by the average temperature prevailing during each second, gives the fraction of a degree δ by which more the thermometer in the calorimeter would have gone up, if there had been no loss of heat by radiation and by the cooling influence of the air.

The average temperature during the s seconds (45″) while the thermometer ascended having been

$$\frac{\tau + \tau_1}{2} \text{ degrees,}$$

we have

$$\delta = \frac{\tau + \tau_1}{2} \cdot s \cdot k$$

or the real number of degrees by which the brine in the calorimeter was heated up was $\tau_1 + \delta - \tau$ degrees.

We observed

$$\tau = 21^\circ{\cdot}20 \qquad \frac{\tau + \tau_1}{2} = 24^\circ{\cdot}625 \qquad s = 45''$$

$$\tau_1 = 28^\circ{\cdot}05$$

$$\tau_1 - \tau_2 = 0^\circ{\cdot}10$$

$$\tau_2 = 27^\circ{\cdot}95$$

$$\tau_2 - \tau_3 = 0^\circ{\cdot}05$$

$$\tau_3 = 27^\circ{\cdot}90$$

$$\tau_3 - \tau_4 = 0^\circ{\cdot}04$$

$$\tau_4 = 27^\circ{\cdot}86$$

$$\tau_4 - \tau_5 = 0^\circ{\cdot}02$$

$$\tau_5 = 27^\circ{\cdot}84$$

Introducing these figures into the equations above-mentioned, we obtain

$$\left.\begin{array}{l} k_1 = 0{\cdot}000060 \\ k_2 = 0{\cdot}000030 \\ k_3 = 0{\cdot}000024 \\ k_4 = 0{\cdot}000012 \end{array}\right\} k = 0{\cdot}000031$$

Hence follows $\delta = 24{\cdot}625 \,.\, 0{\cdot}000031 \,.\, 45 = 0^\circ{\cdot}034$ and $\tau_1 + \delta = 28^\circ{\cdot}084$ and $\tau_1 + \delta - \tau = 6^\circ{\cdot}884$.

Introducing this correction into equation (2) we obtain equation

$$x\, m\, (\tau_1 + \delta - \tau) + \sigma\, \mu\, (\tau_1 + \delta - \tau) + \sigma_2\, \mu_2\, (\tau_1 + \delta - \tau)$$
$$= \sigma\, M\, [\,T - (\tau_1 + \delta)] \qquad (3)$$

and by dissolving it for x we have

$$x = \frac{\sigma\, [M\, (\,T - (\tau_1 + \delta)\,) - \mu\, (\tau_1 + \delta - \tau)] - \mu_2\, \sigma_2\, (\tau_1 + \delta - \tau)}{m\, (\tau_1 + \delta - \tau)}$$

$$= 0{\cdot}79053$$

AUTHENTICAL PROOFS FOR THE SPECIFIC HEAT OF BRINE OF 1·1875 SP. GR.

	I.	II.	III.	IV.
M,	446·0 grs.	446·0	446·0	446·0
μ,	75·2 "	75·2	75·2	75·2
σ,	0·0939	0·0939	0·0939	0·0939
$\mu_2\ \sigma_2$,	1·75 grs.	1·75	1·75	1·75
m,	510·0 "	510·0	510·0	510·0
T,	95°·74	95·85	95·77	96·04
τ,	21°·36	21·84	21·20	21·50
τ_1,	28°·22	28·62	28·05	28·36
τ_2,	28°·15	28·57	27·95	28·27
τ_3,	28°·12	28·54	27·90	28·20
τ_4,	28°·11	28·50	27·86	28·16
τ_5,	28°·10	28·46	27·84	28·11
$\tau_1 - \tau_2$,	0°·07	0·05	0·10	0·09
$\tau_2 - \tau_3$,	0°·03	0·04	0·05	0·07
$\tau_3 - \tau_4$,	0°·01	0·04	0·04	0·05
$\tau_4 - \tau_5$,	0°·01	0·03	0·02	0·04
k,	0·000018	0·000017	0·000031	0·000037
s,	60″	100	45	50
δ,	0°·0268	0·043	0·034	0·045
$\tau_1 + \delta$,	28°·2468	28·663	28·084	28·405
$\tau_1 + \delta - \tau$,	6·8868	6·823	6·884	6·905
$T - (\tau_1 + \delta)$.	67·4932	67·187	67·686	67·635
χ,	0·78778	0·79180	0·79053	0·78732

Average of χ, ... 0·78936

This average value diffe s from the highest value obtained, ... 0·31 per cent.
This average value differs from the smallest value obtained, ... 0·26 per cent.

If we have to determine the specific heat of a solid body which is soluble in water (in this case salt), we put a weighed quantity of it in the basket T which, of course, is to be made of brass sheathing in this case, and in the calorimeter $h\ i\ k\ l$ a liquid which does not dissolve the body (in this case mineral oil), and the specific heat of which is known.

If M_1 means the weight of the salt, filled into the basket;
m_1 means the weight of the mineral oil;
σ_1 means its specific heat;
μ_1 means the weight of the empty brass basket;
x_1 means the specific heat of the salt that is to be determined, the other letters having the same meaning as formerly;

we arrive at the following equation:

$$x_1 = \frac{\sigma_1 m_1 (\tau_1 + \delta - \tau) + \mu_2 \sigma_2 (\tau_1 + \delta - \tau) + \sigma [\mu (\tau_1 + \delta - \tau) - \mu_1 (T - (\tau_1 + \delta))]}{M_1 (T - (\tau_1 + \delta))}$$

I obtained as average figure of the specific heat of salt 0·228.

ADDITIONAL NOTES ON THE COMPOSITION OF THE LIQUID AMMONIA OF THE TRADE, ETC.

By Dr. Hans von Strombeck.

A few weeks ago, just after my paper "On the Composition of the Liquid Ammonia of the Trade" had been presented to the Chemical Section of the Institute, Mr. Louis Block, Chief Engineer of the De La Vergne Refrigerating Machine Company, showed me a piece of a black, dough-like paste which had been scraped out of the compressor of a refrigerating machine. He said that this paste had interfered with the proper working of the valves of the compressor, and thus with the proper working of the whole plant, and requested me to ascertain how this paste could have been formed, and how its formation could be prevented. The weight of the paste scraped out was only 35·24 grains or about one-twelfth ounce. As a superficial examination of the paste showed the presence of a considerable percentage of iron, I thought first that the mineral oil used in the compressor might contain some mineral acid or some fatty oil which by setting free fatty acid had acted on the valves of the compressor. But an examination of the oil used proved it to be pure mineral oil of the same chemical and physical

properties as usual. I then made a thorough analysis of the black paste; that is to say, as thorough as the small available quantity of substance allowed.

The 35·24 grains of the black paste consist of:

Grains.		*Per Cent.*	
3·0860	=	8·7565	of moisture.
4·2278	=	11·9965	of mineral oil.
0·0092	=	0·0260	of ammonium-sulphide.
0·1137	=	0·3227	of sulphate of ammonia.
0·0779	=	0·2210	of ammonium-chloride.
6·2489	=	17·7324	of organic matter soluble in water.
6·5302	=	18·5301	of peroxide of iron.
0·7601	=	2·1569	of iron-sulphide.
14·1862	=	40·2579	of (by difference) insoluble organic matter.
35·2400		100·0000	

The kind of bodies found made me suppose that the formation of the black paste is due to the action of impurities contained in the liquid ammonia on the valves and the oil in the compressor, and the analyses of five liquid ammonias, which had been made of different raw materials and by different processes, prove that my supposition was correct:

	G. Per Cent.	*H.* Per Cent.	*I.* Per Cent.	*K.* Per Cent.	*L.* Per Cent.
Ammonia (by difference), . .	97·9260	98·8040	99·9304	99·9449	99·3115
Colorless fluid, ...	1·4322	0·9734	0·0307	0·0084	0·0270
Moisture, ...	0·5882	0·1962	0·0281	0·0260	0·0266
Mineral oil, ...	0·0158	0·0120	0·0032	0·0038	0·0108
Hartshorn salt of ammonia, .	0·0304	0·0094	0·0064	0·0159	0·0235
Ammonium-sulphide, ...	0·0008	0·0033	0·0002	0·0005	0·0002
Sulphate of ammonia, ...	0·0042	0·0014	0·0004	0·0005	traces
Ammonium-chloride, ...	0·0002	0·0001	traces	traces	0·0004
Mineral matter suspended, . .	0·0022	0·0002	0·0006	traces	traces
	100·0000	100·0000	100·0000	100·0000	100·0000

Sample *L* contains also some resinous matter. Now it seems impossible that such small quantities of ammonium-sulphide and chloride, sulphate and carbonate of ammonia as found in these ammonias can destroy enough iron and oil to explain the presence of the black paste. For, if we take a plant in which 2,000 pounds of such ammonia as analyzed under *G* circulate, the contaminations contained in the 2,000 pounds can only eat off 0·44 pounds of iron. By distributing this loss of iron over the whole interior surface of the pipes, etc., of the plant; that is to say, over a surface

of 1,000 square feet and more, it will be seen that the loss undergone by the valves is only infinitesimally small. Thus the damage done by these contaminations would be equal to nothing if the reaction between the acids contained in them and the metal took place only *once* and stopped as soon as the formation of the neutral salt had taken place. But this is not so. By the electricity generated by the working of a refrigerating plant the sulphate and carbonate of ammonia, the ammonium-sulphide and chloride are decomposed, their acids combining with the iron of the pipes, etc., and decomposing the oil. The iron salts thus formed afterwards dissolve in the water, always sufficiently present, and in the ammonia and are transformed again into sulphate, etc., of ammonia, the iron being separated out and being more or less oxidized by the oxygen of the air, which is always present in small quantities. The newly formed sulphate, etc., of ammonia is decomposed again by the electric current, and so on, a continuous circuit being formed. In this way by a very small quantity of impurities of this kind, considerable quantities of iron and oil, can be destroyed and the proper working of the plant interfered with, the latter so much more, as in its most sensitive point in the compressor the action of the acids is most energetic because of the high temperature (150°) prevailing there.

To avoid the formation of such a black paste and its unpleasant consequences it is therefore necessary to use in a refrigerating machine only such liquid ammonias out of which all ammoniacal salts have been removed. While this removal can be done in different ways, my new process of purifying ammonia (described in the July number of this journal) simultaneously with the other impurities stated, also takes these ammoniacal salts out, the reactions being the same as described in equation (III) viz:

$$\text{(IV)} \quad (NH_4)_2\,So_4 + Na_2 = Na_2\,So_4 + 2NH_3 + H_2$$

$$\text{(V)} \quad (NH_4)_2\,S + Na_2 = Na_2\,S + 2NH_3 + H_2$$

$$\text{(VI)} \quad 2NH_4\,Cl + Na_2 = 2NaCl + 2NH_3 + H_2$$

LABORATORY OF THE
DE LA VERGNE REFRIGERATING MACHINE COMPANY,
NEW YORK, July 18, 1892.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

North, S. N. D. *The Wool Book.* Boston: Rockwell & Churchill. 1892. 16mo.

Peabody, C. H. *Valve Gears for Steam Engines.* New York: J. Wiley & Sons. 1892. 8vo. $2.50.

Picon, R. V. *Distribution de l'Électricité par usines centrale.* Paris: Gauthier-Villars. 1892. 12mo. 3 francs.

Railway Official's Directory. Chicago: *Railway Age.* 1892. 32mo.

Tesla, N. *Experiments with Alternate Currents of High Potential and High Frequency.* New York: W. J. Johnston Company. 1892. 16mo. $1.

Witz, A. *Thermo-dynamique à l'usage des Ingenieurs.* Paris: Gauthier-Villars. 1892. 12mo. 3 francs.

Alheilig, M. *Recette, Conservation et Travail des Bois.* Paris: Gauthier-Villars. 1892. 12mo. 3 francs.

Duhem, P. *Lecons sur l'Électricité et le Magnetisme. Tome 3. Les Courants Linéaires.* Paris: Gauthiers-Villars. 1892. 8vo. 15 francs.

TABULATED RESULTS OF THE LAUFFEN-FRANKFORT TRANSMISSION.

We quote from the issue of June 17, 1892, of the (London) *Electrician*, the tabulated results of the famous Lauffen-Frankfort transmission of some 300 horse-power by means of high potential currents through a distance of about 109 miles.

The difference of potential on the line varied from 25,000 to 30,000 volts. The plant, which is only to be regarded as an experimental one, and notwithstanding the difficulties to be overcome, was able to show, as the result of some seventeen runs, an average efficiency between turbines and consuming apparatus of 73·3 per cent. Such figures show the wonderful efficiency of the electrical transmission of power as compared with any other method.

Table I, gives the results for the Lauffen-Frankfort transmission. Table II gives the results of a shorter transmission circuit of only one and one-fourth miles. The average total efficiency of eight runs in the latter case was 83·1 per cent.

The measurements in the first case were made by Profs. Dietrich, Stenger, Teichmann, Voit and Weber, Drs. Heins and Kopp, and Messrs. Nizzola and Schmoller. Those in the second case were made by Prof. Brauer, Dr. Wirtz, and Messrs. Friesse, Stapelfeldt and César. E. J. H.

TABLE I.—LAUFFEN TO FRANKFORT.

Time.	Horse-power Supplied by Turbine.*	Output of Dynamo.	Efficiency of Dynamo.	Output of Primary Transformer.	Efficiency of Primary Transformer.	Loss in Conductor.	Energy Supplied to Secondary Transformer.	Energy Delivered by Secondary Transformer.	Efficiency of Secondary Transformer.	Efficiency between Dynamo and Consuming Apparatus.	Efficiency between Turbines and Consuming Apparatus.	Weather.
	horse-power	*horse-power*		*horse-power*		*horse-power*	*horse-power*	*horse-power*		*per cent.*	*per cent.*	
Oct. 11th — 1.30 to 1.40 . .	120·9	108·1	0·894	102·4	0·947	7·3	95·1	89·5	0·941	82·6	74·0	Bright,
1.50 to 2. 0 . .	121·1	108·3	0·894	102·6	0·947	7·6	95·0	89·4	0·941	82·4	73·8	Dry.
Oct. 12th.— 1.35 to 1.45 . .	127·0	114·4	0·900	108·7	0·950	8·0	100·7	95·1	0·944	83·0	74·9	Cloudy,
1.50 to 2. 0 . .	127·5	114·8	0·900	109·0	0·950	8·1	100·9	95·3	0·944	82·9	74·8	Rain at
2.10 to 2.20 . .	99·3	86·8	0.874	81·5	0·939	5·0	76·5	71·4	0·933	82·4	71·9	Times.
Oct. 13th.— 9.50 to 10. 0 . .	105·9	93·3	0·881	87·7	0·940	6·0	81·7	76·3	0·934	81·6	72·1	Rain till
10. 5 to 10.15 . .	105·9	93·3	0·881	87·7	0·940	5·9	81·8	76·4	0·934	81·7	72·2	Noon.
Oct. 14th.—10.45 to 10.55 . .	151·8	139·1	0·916	132·8	0·955	12·8	120·0	114·0	0·950	81·8	75·1	
11. 0 to 11.10 . .	151·7	139·0	0·916	132·7	0·991	12·5	120·2	114·2	0·950	82·0	75·3	
11·35 to 11.45 . .	194·7	182·2	0·935	175·1	0·961	24·4	150·7	144·2	0·957	79·1	74·1	
12.30 to 12.40 . .	197·4	184·8	0·935	177·6	0·961	25·2	152·4	145·8	0·957	78·8	73·9	Dry.
1.30 to 1.40 . .	117·6	104·9	0·892	99·2	0·946	7·5	91·7	86·2	0·940	82·0	73·3	
1.45 to 1.55 . .	112·7	100·1	0·888	94·5	0·944	6·9	87·5	82·2	0·938	81·9	72·9	
2.30 to 2.40 . .	78·2	66·1	0·845	61·1	0,925	3·1	58·0	53·5	0·922	80·9	68·5	
Oct. 15th.—10.53 to 11. 3 . .	190·7	177·9	0·933	170·8	0·960	25·5	145·3	138·9	0 956	77·8	72·8	Rain in
11. 5 to 11.15 . .	190·0	177·3	0·933	170·2	0·960	24·9	145·3	138·9	0·956	78·1	73·1	Early
11.20 to 11.30 . .	189·7	177·0	0·933	169·9	0·960	24·6	145·3	138·9	0·956	78·1	73·2	Morning.

* The energy taken by exciter is included.

TABLE II.—PALMENGARTEN TO FRANKFORT EXHIBITION.

Primary Station. Dynamo by Deutsche Elektricitätswerke Aachen.				Secondary Machine. Motor by Deutsche Elektricitätswerke Aachen.							
Volts at Terminals.	Current in Ampères.	Total Output, Watts.	Revolutions per Minute.	Volts at Terminals.	Current in Ampères.	Energy Absorbed by Motor.	Revolutions per Minute.	Load on Brake Lever, Kgs.	Load Horse-power.	Efficiency of Motor.	Total Efficiency.
1,107	13·95	15,442	511	1,045	13·95	14,578	370	15	17·44	88·10	83·10
1,124	13·90	15,624	519	1,043	13·90	14,464	375	15	17·68	89·70	83·30
977	10·55	10,307	528	932	10·55	9,832	358	5	11·87	88·80	84·70
992	10·75	10,664	526	927	10·75	9,955	361	5	11·98	88·30	82·70
1,001	10·90	10,911	527	934	10·90	10,181	364	5	12·07	87·30	81·40
970	9.70	9,408	539	899	9·70	8,720	402	0	10·52	88·70	82·10
946	9·65	6,129	538	884	9·65	8,531	392	0	10·24	88·40	82·60
941	9·65	9,081	536	896	9·65	8,646	400	0	10·46	89·10	84·80
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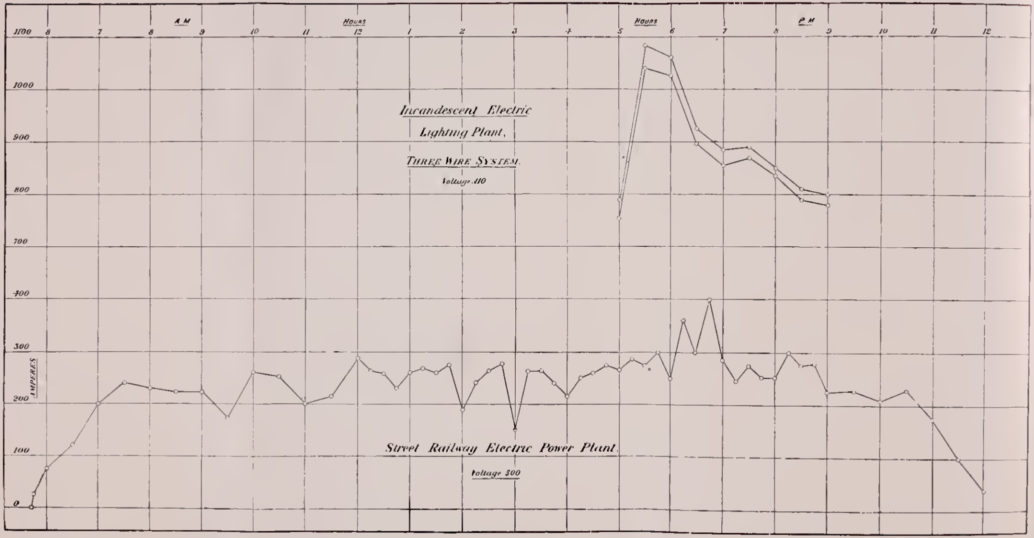
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Incandescent Electric
Lighting Plant.
Three Wire System.
Voltage 110
Street Railway Electric Power Plant.
Voltage 500

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THE ELECTRIC TRANSMISSION OF POWER.

BY EUGENE GRIFFIN.

[*A lecture delivered before the Franklin Institute, February 29, 1892.*]

Although the use of electricity for power purposes has increased enormously during the past three years—and there are few, if any, who do not daily see this power in operation—it is a surprising fact that many, perhaps the majority of mankind, do not realize that electricity is not an initial power, but only a convenient form into which energy may be transformed for transmission to some distant point. The newspapers speak of electricity supplanting steam. This is not true in the sense in which the words are used. Electric motors may supplant steam locomotives as the immediate power for hauling cars on railroads, but the steam-power is simply transferred from the locomotive to a large stationary engine at some central station where it

runs the dynamos, and is by no means eliminated from the problem.

The average layman does not reflect that we must have some means of generating electricity, and that the usual method is the application of steam-power to a dynamo. In one sense we must go back to the sun as the original source of energy. For thousands of years the sun has been storing up energy in the form of coal, and we are now using this stored energy for practical purposes. Every lump of coal contains the potentiality of a given quantity of horse-power, or rather from this coal may be obtained a given amount of energy which we measure in units of horse-power. We convert this energy into steam in the boilers, we again convert it into mechanical motion in the engine, again it is changed into electricity in the dynamo and goes out over the wires to be once more transformed into light, heat or motion.

The advantages of generating power in one place to use in another or in several other places, are too many and too obvious to require consideration. In many cases it is absolutely necessary to generate the power at some distant point. In case of waterfalls we have the power existing and running to waste and it is only necessary to utilize it as it is. We may, by pipes, canals and conduits, conduct this water-power to the place where we want to use it, but we can only conduct it down hill. Steam-power can be converted into mechanical power and by belts and shafting carried in any direction, but the distance is limited and the loss in power rapidly increases with the distance. Electric power can be carried in the wires in any direction, up or down, around corners, underground, in the air, wherever the conditions are most favorable, and can be carried longer distances with less loss than any other form of energy. These advantages are so manifest and so important that it is only surprising that electric energy is not more generally used than it is.

Electrical energy is manifested in many ways and is generated by numerous methods; but the only practical method of generation with which we need be concerned is the dynamo; *i.e.*, closed wire coils revolving in a magnetic

field. There are dynamos and dynamos, and it may be well to consider for a moment the different kinds of current which they generate. Dynamos are classified in many ways, as shunt wound, self exciting, separately excited, etc., but the only differences that I care to examine now are those which affect the character of the current produced. The alternating machine is a dynamo in which electric currents are generated in the armature coils, as these coils approach, come opposite to and recede from the magnetic fields of one or more magnets. The ordinary machines have six or more electric magnets placed around the periphery of the frame, and the armature turns in close proximity to the magnets and the field coils which surround the iron cores and form part of the magnets. The electrical impulse or current generated in the armature coil as it approaches a magnet, is in one direction, and as it recedes from the magnet is in the other direction; and so we have a series of impulses alternating in direction, and which for comparative purposes we call positive and negative. Assuming a neutral line, we represent an alternating current graphically by a wave line with equal ordinates above and below the axis. In the direct-current dynamo we commutate the current; *i. e.*, we so arrange the contacts or connections with the wire that leads the current away from the dynamo that these contacts change as the impulses change, so that the impulses are always in the same direction in the lead wire, and we have a constant or direct current which we represent graphically by a straight line.

If the constant current dynamo with its two fixed brushes be supplied with a third brush so arranged that it revolves about the commutator with greater or less rapidity, we have a peculiar result which we call a pulsating direct current. This is used practically to operate a rock drill constructed on the solenoid principle, as follows:

The upper and lower brushes are fixed; the third or revolving brush is shown in its neutral position. When in this position, or when it has revolved 180° from this position there is manifestly no current in the third or middle wire. As the revolving brush approaches the upper brush, the

middle wire takes part of the current of the upper wire and as it approaches the lower brush it takes part of the current of the lower wire. The result is an alternation of pulsations through the upper and lower halves of the solenoid varying in rapidity directly with the rapidity of rotation of the third brush. The drill in the solenoid is drawn up and down with rapidity dependent upon the rapidity of the electrical impulses. This peculiar current is graphically represented on accompanying plate.

You have all doubtless heard of the long-distance power transmission installation recently exhibited at the Frankfort Exhibition in Germany. In this installation still another kind of current is used, called the three-phase current. Three separate impulses are generated in each revolution of the armature, each lagging 120° behind the previous impulse. This dynamo is practically an alternating dynamo and the current generated bears somewhat the same relation to the ordinary alternating current as the pulsating direct current does to the ordinary simple constant current obtained from a two-brush machine. The three-phase current is graphically represented on accompanying plate.

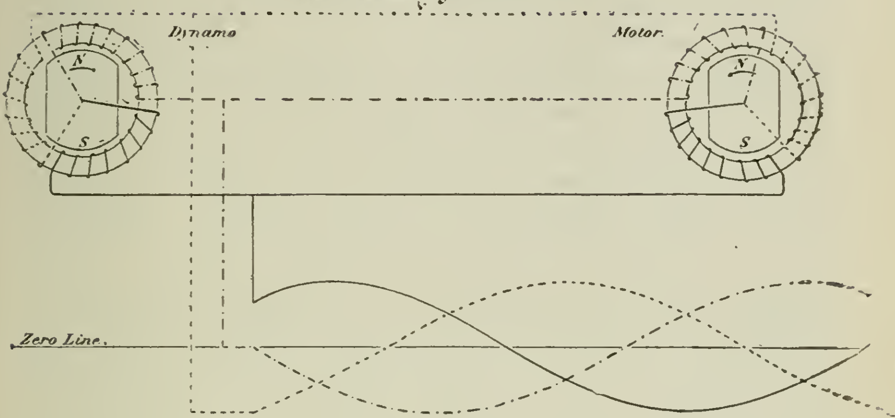
In the electrical transmission of power are involved four elements:

(1) The original power.
(2) The generator.
(3) The line.
(4) The motor.

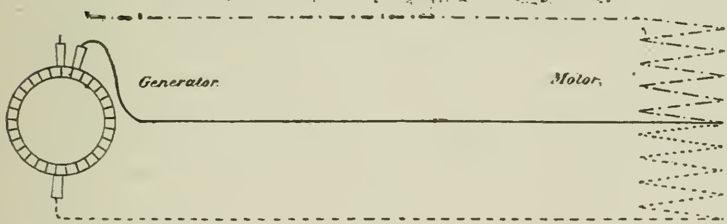
The original power is usually steam; sometimes water. If the power consumed at the other end of the line is constant; *i. e.*, if the load on the engine is constant, or if the changes in load are gradual, the problem is simple, so far as the steam engine is concerned, and any of the ordinary types of engine will do the work. For street railway and similar work where the loads are variable, especially strong engines are required to stand the enormous strains resulting from the sudden and very violent fluctuations. The same build of engine which did good work in an electric lighting station was found to be too light for railway work.

Engineers are not yet agreed as to whether high- or low-

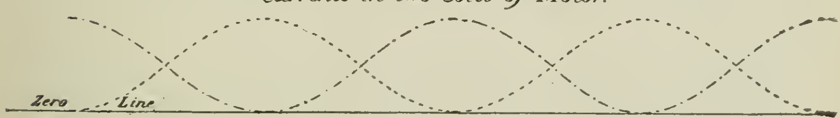
Three Phase System.



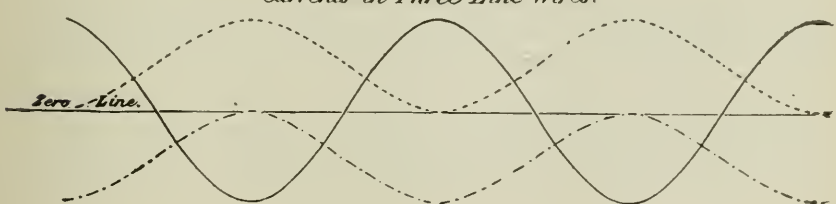
Van Depoele Pulsating Current System.



Currents in two Coils of Motor.



Currents in Three Line Wires.



speed engines are preferable for power stations, but the weight of opinion seems to be in favor of slow speed. High-speed engines with direct belting gives one engine to one, two, or sometimes three and even four generators, independent units which can be shut down or started, one after another, to meet the demands on the station, and permits of multiplication of units so that a break down of one unit, either steam or electrical, only throws out of service a small fraction of the station capacity. Against this lies the fact that injury to the engine throws out the dynamos as well as *vice versa.* With large, slow-speed engines, and counter-shafting, any dynamo or group of dynamos can be run from any engine. Against the greater coal economy of the slow-speed engine is to be urged the loss of power in the counter-shaft and belting. Of late the method of direct coupling, making the engine and dynamo practically one machine, is meeting with more favor and for large sized generators this method undoubtedly has a future. The engine and dynamo are mounted on the same shaft.

The latest types of dynamo are built to run with slow armature speed, and in this respect the electrical manufacturers are gradually approaching the engine makers.

Uniform armature speed is essential to maintenance of constant potential and the engines should have perfect governors. Many faults attributed to the electrical apparatus have been found on investigation to be really due to poor engines, imperfect governors, slipping belts, low steam pressure or other cause remote from the electrical apparatus.

Engines work most economically under full load. Unfortunately constant loads are not the rule in electrical work, and as the loads vary the mean must be somewhat below full load. A mean of several electric railway power stations shows the average load to be about sixty per cent. of the maximum, and in lighting stations running for twenty-four hours the changes are, of course, much greater. In the latter case it is imperative that the steam plant be divided into numerous units which can be gradually brought into service according to the demands. Arc lighting work is fairly

constant. Street lights burn all night or on moonlight schedules, and are all started and stopped at the same time. Commercial lights may burn till midnight. The limitations are known and can be provided for. Incandescent work, particularly with meters, is more variable. Referring to the plate of curves shown herewith, the upper lines show the current output in ampères during four hours for an incandescent station having a maximum capacity of 4,000 lights. This is probably a fair sample of this service. The lower line shows the current output in ampères of an electric railway power station for eighteen hours.

From this it appears that, the average being well below the maximum, the engines are not working to the best advantage and the greatest coal economy is not attainable. In Europe, this is obviated to some extent by adding a storage battery to the station equipment. The steam plant is then proportioned to the mean demand for power and runs constantly at full load. When the demand for power falls below this mean, the extra current generated is directed into the storage battery. When the demand exceeds the capacity of the engines and dynamos the extra current is supplied from the batteries. The cost and maintenance of the batteries in this method must be balanced against the cost and maintenance of the extra steam and generator plant in the first method, and the less economical operation. It is a striking fact that storage batteries are used to a very large extent in foreign stations (not necessarily in all cases in the way above indicated) and rarely, if at all, used in this country. One would suppose that the actual results would long since have determined in which method true economy is to be found, but so far the engineers on the two sides of the Atlantic have not been able to agree. The practice differs also in another respect. In Europe rope belting is largely used, while in this country it is rarely found and has been condemned in one or two places where it has apparently had a fair trial.

(2) *The Generator.*—The kind of generator used depends upon the method of utilizing the electrical energy produced.

The arc lighting dynamo is made to generate a current of constant quantity and potential varying with the number of lamps on the machine. The incandescent direct-current dynamo generates a current of constant potential and quantity varying with the number of lights. The railway or ordinary power generator is similar to the incandescent direct-current machine. The alternating-current dynamo produces a current suitable for incandescent lighting, but so far it has not been made available for power work as the alternating motor has little torque and therefore cannot start under a load. The pulsating direct-current machine is the ordinary direct incandescent dynamo with a third brush added and is used as before stated. The three-phase current dynamo has no commutator, runs noiselessly, and can be used for power purposes as the motor has sufficient torque to start with a load.

In the synchronous method of transmitting power by alternating currents, it is necessary to start the motor by some exterior power; but if proper arrangements are made, the starting is no more difficult or tedious an operation than the starting of a large Corliss steam plant.

The synchronous motor when overloaded "lies down" and declines to do any work at all until the load is reduced to proper limits.

The synchronous alternating motor has an excellent quality in which it is only equalled by the plain shunt-wound motor of the every-day electric lighting station. It regulates perfectly as to speed, keeping in step, within the limits of its capacity, with the generator which drives it.

The non-synchronous type of motor, in connection with the three-phase current, presents many features of superiority over the synchronous, in that its speed will not vary more than a few per cent. from light to full load, and also from the fact that it will start under full load, and requires no exciting current. A field is set up by three conductors conveying currents of three-phase character, in a laminated iron mass, which field is made to rotate, and drags around a movable iron armature on which is a system of closed coils, or coils which can be closed, these coils having strong

currents induced in them by the moving lines of the field. Thus, the rotating magnetic lines in cutting the armature conductor, push the conductor along by virtue of the reaction of opposing currents set up in the conductors of the armature, or closed circuits. These motors are not capable of being used as generators when revolved by exterior power. The great advantages of this method are that the motors can be started and stopped at will, and have no commutators.

The sizes of the dynamos have greatly increased in the last three years. We have now seventy-light arc dynamos, 2,800-light direct incandescent machines; Ferranti's 100,000, sixteen candle-power light alternating (10,000 horse-power) dynamos; and 670 horse-power generators for power use.

The Thomson-Houston Company are now building seventeen of these large power dynamos for the West End Street Railway of Boston.

In increasing the sizes of dynamos a change from the bi-polar type of the smaller dynamos has been found necessary, and the large machines are made with not less than four poles. Slower speed of the armature is a natural advantage, and many other improvements are to be found in the latest type of power dynamos.

The size of the dynamo should be proportioned to the total work at the station. There should never be less than two generator units, and preferable more. With a total of 250 horse-power, it would be poor practice to have but one 250-horse-power dynamo. Three eighties would be far preferable. With a total of 2,000 horse-power, it would be poor practice to have twenty-five eighty-horse-power dynamos. Eight 250's would be preferable.

The switchboard should be provided with every possible safety device to automatically prevent overloading of the dynamos, injury to the machines from lightning, and to automatically throw off the current in case of short circuit on the line resulting from crosses with the line wires or accidents of such nature.

(3) *The Line.*—Having converted the power into the form of electrical energy, we now must transport it to

the place where it is to be used. The line wires do this. For lighting, the lamp is the place where the energy is to be utilized, and the wire leading from the dynamo to the lamp may be thoroughly insulated and placed overhead, underground or anywhere so far as fulfilling its duty in this respect. In railway work, we want the current at variable points over many miles of streets, and this can only be obtained by the use of bare conductors and brushing, sliding, or rolling contacts. It is this essential difference between railway and lighting work that prevents us from placing the railway wire underground as we do the lighting wire. The railway wire must be bare in order that we may obtain electrical contact every fraction of inch from one end to the other. To place this bare wire in a hole in the ground and keep it securely insulated from the ground, to keep the width of the slot down to safe dimensions, and yet work the conducting plow which must be absolutely insulated from both sides of the slot, has been found to be no easy task. Every practical trial in this country has failed.

(4) *The Motor.*—The motor is simply the dynamo reversed in its operation, and the various forms are those best suited to the varying conditions of use.

Several different systems have been successfully used for long distance transmission, but the alternating has proved most successful. The difficulty of handling a potential of over 2,000 volts direct current has hindered progress in this direction. The sparking between the segments of the commutators in these dynamos and the difficulty of insulating for such high pressure have been sources of trouble. In the alternating, where a low potential can be developed in the dynamo, and by the use of step-up transformers, raised to any desired height, this difficulty is avoided.

The following are some of the actual examples of electrical transmission which we find abroad and at home.

Many of the large water-falls of Europe, notably of Switzerland, are now being utilized, and the neighboring cities and towns lighted by electricity, transmitted distances ranging up to 112 miles.

Probably the most notable plant ever constructed is that of the Frankfort Exhibition, where over 300 horse-power was transmitted 112 miles by means of three slender bare wires No. 4 B and S gauge.

Lauffen, where the generating station was located, is situated on the Necker, a branch of the Rhine, and the enormous water-power was utilized to generate 300 horse-power of electrical energy at a tension of from 16,000 to 30,000 volts.

At Lauffen step-up transformers were used to increase the potential from the fifty volts of the dynamos to these very high pressures used, and at the other end of the line, namely, in the grounds of the electrical exhibit, step-down transformers re-converted the pressure to a point where it could be utilized for both light and power uses.

An immense bank of lamps, wired up in series, gave evidence of the high voltage of the line. In only one case did the insulation break down, and that was at a strain of 30,000 volts.

An interesting feature of the installation was the supplying of an artificial cascade, thirty feet high, with water pumped by means of the electrical current, thus completing the cycle of changes. The experiment was undertaken more as a matter of scientific investigation than an attempt at commercial success. An efficiency of seventy-four per cent., however, was obtained.

The cost of the installation per effective horse-power based on the assumption of 300 horse-power delivered at Frankfort, was a little over $300, of which the cost of the line involved $210.

During the progress of the exhibition, the plant was run at a potential of 16,000 volts. At the close, however, experiments were made at a very much higher pressure. The insulators were made in three sections. The porcelain top was flat with a deep groove to hold the wire, and underneath a saucer-shaped receptacle. Beneath this was another receptacle of larger breadth and depth, and under this still another. All were filled with oil. On final experiments the pressure was increased to 20,000 and finally 30,000 volts.

Though none of the insulators gave way a plate of glass was easily punctured. It is believed that these insulators, somewhat modified in form, can readily be made to stand a pressure of 50,000 volts.

During the experiments regular readings were taken at both ends of the line, and voltmeter readings were taken between one conductor and the neutral point in each of the three circuits, which averaged fifty-four volts, the current readings being 500, 490 and 500 ampères, respectively, in the primary circuits. The mean electric power delivered to the line was 80,500 watts. At the same time the Frankfort end of the line delivered current for 1,060 incandescent lamps of sixteen candle-power which absorbed about 58,000 watts. These figures give the seventy-four per cent. efficiency which it is claimed is low owing to the lag. Wet weather was not found to appreciably affect the working of the line. The losses due to condenser action of the conductors was also found to be very small.

A description of the Lauffen-Frankfort transmission plant is not complete without brief reference to the permanent transmission of power from this point; to-wit: Lauffen to Heilbronn, a distance of seven and one-half miles. The plant is owned by the Lauffen-Portland Cement Company, and the power, besides running their work, also supplies the city of Heilbronn with light. The power plant is of 1,500 horse-power capacity, of which 600 horse-power is used for the cement works, leaving 900 horse-power for the supply of light and power. The alternating current system is used on account of the great distance the current is transmitted. A 300 horse-power rotary-current dynamo with a capacity of 4,000 ampères at fifty volts is used. This current is transformed to 5,000 volts. The transmission is by three sets of bare wires, ·24 inch in diameter carried on overhead poles with oil insulators. An ingenious device for protection against lightning is the placing of an ordinary barb wire above the wires on the pole, and connecting with earth at frequent intervals. At the outskirts of the town of Heilbronn the current passes through a large transformer similar in type to that at the Lauffen end,

which transforms the current down from 5,000 to 1,500 volts. From here it is conveyed by concentric cables underground. At more central points other transformers are located which reduce the potential down to its final pressure of 100 volts, at which it is supplied to customers.

The total loss in the seven and one-half miles of leads and in the double transformation is said to be only twenty per cent., 160,000 watts of the 200,000 generated at Lauffen being available to customers. This is sufficient for 3,200 incandescent lamps of sixteen candle-power.

Another interesting plant is the generating station located at the villa town of Tivoli, Italy, which is situated in the Sabine Hills eighteen and one-half miles from Rome. The practically unlimited water-power of the river Amene is used at this point to drive water-wheels. The current generated is utilized for light and power in Rome.

The motive-power is derived from a water flow of about 132 cubic feet under a head of 157 feet.

Six turbines of 300 horse-power each, are coupled direct to alternating dynamos, 230,000 watts capacity, at 170 revolutions a minute.

In addition there are three direct-current machines, each coupled to a turbine making 375 revolutions, which are used as exciters for the alternators.

At full load, a potential of 5,100 volts is used. The current is conducted by means of four bare copper wires (between Nos. 7 and 8 B and S gauge), carried on iron poles with oil insulators.

The drop in potential amounts to twenty per cent. on a line of 18·4 miles (circuit 36·8 miles). At the outskirt of Rome near Porta Pia, is located the distributing tower in which the current is transformed from the pressure of 5,000 to one of 2,000 volts. This is again reduced at centrally-located points to 100 volts, at which it is furnished customers.

When fully completed the central station of Rome with its 5,000 horse-power capacity will be the second largest lighting plant of Europe, Berlin having the largest.

The town of Pontresina is situated in the Engadin Valley, at an elevation of some 6,000 feet above the sea.

The lighting plant was designed and constructed by the firm of R. Alioth et Cie, of Basle, and is one of the somewhat uncommon direct-current transformer systems.

About four miles south of Pontresina, at the base of the famous Morteratsch glacier, are the falls of the Bernina.

A portion of the stream above the falls is diverted to a small reservoir from which it is conveyed by a cast-iron pipe to the power station at the foot of the mountain. It is used to drive the turbines to which the dynamos are coupled.

The maximum rate of water discharge is over seventy gallons a second with a head of 420 feet.

Seventy-five horse-power high pressure turbines, built by Escher, Neyss et Cie, of Zurich, are used, each connected independently to a primary dynamo by flexible couplings. The generators have each a capacity of thirty-four ampères, (1,500 volts), or 51,000 watts at 500 revolutions, and are of the four-pole type, series wound.

The turbines are equipped with automatic regulators which maintain a constant speed, this insuring a constant potential at the transforming station under all loads. Three machines are run in series giving a combined capacity of thirty-four ampères, 4,500 volts, 153,000 watts, a fourth being held in reserve in case of breakage. The primary current is conducted by a No. 4 copper wire. Oil insulators are used.

In the transforming station, situated in the centre of Pontresina, the current passes first through meters and safety devices placed on the switchboard, then to the four motor dynamos which are connected in series, the secondary lines being connected in multiple with the service lines.

The number of transformers at work is controlled by a multipole switch, the number running corresponding to the number of generators in operation.

The difference in the construction of the "direct-current transformer" or "motor dynamo" from the ordinary dynamo, consists in the presence of two distinct windings on the

armature each connected to a separate commutator located at the two extremes. Through one set of windings the primary current is passed, causing the armature to revolve, producing the motor action, while in the other a current is generated and conveyed to the service line—the voltage of this latter depending on the same conditions that govern any dynamo.

The current of the secondary, which delivers 280 ampères at 130 volts, is distributed by a second switchboard, fully equipped with all the necessary regulating apparatus, meters and safety devices.

One hundred and twenty arc lamps are used, and the greatest load is 840 ampères at 130 volts. Over 1,700 incandescent lamps of different candle-power are on the circuit beside the arc lamps used for street lighting.

Streets, hotels and private houses are lighted. The plant was erected by the consumers, and is run on the co-operative plan. Every citizen can join by paying his actual part of the expense. The company is in touch with the township from which it derives its water-power rights, and in return it furnishes the street lighting free.

In spite of the distance between the power station and the point of consumption, four miles, the direct-current system was adopted on account of its safety, and the many advantages it afforded in making it possible to add accumu lators to the system, thus increasing the capacity at the heavy period of consumption, and also its greater adaptability for motor service.

A rather novel plant is being constructed at Kioto, Japan. In this case, the water of a lake some nine or ten miles distant from the city, will be brought through pipes to a distance of about two miles from the city limits. Here it will be used to drive electric generators. The power will be used throughout the city for factories and for general lighting and power work. The motors farthest from the generating station will be some four miles distant. Pelton water-wheels of 120 horse-power are to be utilized.

It is estimated that there are fully 200 power stations

operated by water-power in Switzerland alone. Even in the "Dark Continent" of Africa they have long distance electric power transmission plants. The Forbes Cliff Mining Company, of Transvaal, operate Pelton water-wheels coupled direct to Edison dynamos aggregating over 200 horse-power, which is transmitted four miles. The efficiency of the entire system is over seventy per cent.

At St. Brieux, Côtes de Nord, France, two 1,300-light Thomson-Houston alternators are driven by two Hercules turbines of the vertical type, one a 125 horse-power, and the other 150 horse-power. An interesting characteristic of this plant is that the alternators are run in multiple upon the same circuit. The distance from the central station to the centre of distribution is some eight and one-half miles, and the pressure employed 2,000 volts. It is interesting to note that the wires used to convey the current for 2,600 sixteen candle-power incandescent lamps over the distance of eight and one-half miles are ·31 of an inch in diameter.

A power transmission plant at Ayonnax, eastern France, has been in operation since March, 1890. Power is obtained from a 1,750 horse-power fall, five miles from town, where two 105 kilowatt machines are coupled direct to two horizontal turbines. Current is transmitted on the three-wire system to two 120 horse-power motors, driving directly two 125 volt, 600 ampère dynamos. The commercial efficiency is said to be 76·2 per cent.

The power of the 180-foot fall at St. Lorenzen, Austria, will be utilized for running the works of Franz Company, of Marburg, eighteen miles distant. Of the 600 horse-power available, it is expected to utilize about 450 at the works. Total cost of plant estimated at about $110,000.

An Anglo-Swiss syndicate has been formed to utilize the power of the Rhine at Laufenberg for the electrical transmission of power. It is intended to make a canal one mile long, and it is estimated that some 7,000 horse-power will be available.

The 45,000 light station at Paris, supplying the Place Clichy sector, has three floors with superficial area of 19,800 square feet. Three 150 horse-power Armington & Sims

engines belted to two shunt-wound dynamos, and three 500 horse-power Corliss engines running at sixty-four revolutions, and coupled direct to 350 kilowatt (700 ampère, 500 volts) eight-pole machines, armatures eleven feet in diameter, run during the day; a 250-cell battery of Laurent-Cely accumulators supplies current during the night. The district has an area of nearly two square miles.

In Guatemala, Central America, a combined arc and incan descent plant has been operated by water-power since the year 1887. Part of the plant consists of two Thomson-Houston 1,500 light alternators. The station is three and three-fourths miles distant from the city. Twenty-one inch Rodney-Hunt turbines of 250 horse-power are used, driving the dynamos by a counter-shafting. The remainder of the plant comprises seven forty-five light 2,000 candle-power arc dynamos, and three eighteen-light machines. This part of the plant is seven and one-half miles away, and receives its power from a fifteen-inch double Rodney-Hunt turbine of 260 horse-power.

The city of Pueblo possesses an electric lighting plant, which is in many ways remarkable. Two hundred arc lights of 1,200 candle-power are run by four fifty-light arc machines in a station some thirteen miles away from the centre of the town. The power is furnished by the river Atoyac, operating a 200 horse-power Leffel double turbine. Each of the four existing circuits is about twenty-six miles in length, and consists of a No. 4 insulated wire. The dam and the masonry of the station itself has been built of fine cut stones, and forms probably one of the most substantial and well-built structures in Mexico.

A contract recently entered into by the Thomson Houston International Electric Company, provides for a plant to be worked by water-power near the town of Pireacicaba, Sao Paulo, Brazil. The system will probably comprise fifty arc lamps of 1,200 candle-power each, and about 2,000 incandescent lamps of the alternating system. In this case the power station will be only about a mile away from the town.

Turning now to the plants in this country, we find that

in the celebrated Comstock Mine, in Nevada, water from the mountain lake has been turned down one of the shafts of the mine for 1,200 feet, and at this depth in the earth a series of specially constructed wheels are located coupled direct to the dynamo machines. This novel plant is still in successful operation. It consists of six generators, ranging from 100 to 120 horse-power capacity each, and six motors of sixty horse-power each.

As so much has been said in the papers recently about the Niagara power plant, the forces exerted by this immense volume of water may be of interest.

Some 21,000,000 cubic feet of water pass over the head of Niagara every minute.

The idea of the great Niagara tunnel is said to have originated with the late Thomas Evershed. The tunnel or tail race, is to extend from the surface of the water level below the falls to a point on Niagara River above the Falls. It is to be connected with the river by means of short surface canals, wheel pits and cross channels.

The power expected to be produced by the capacity of the tunnel will be equal to the water-power of Lawrence, Lowell, Holyoke, Turner Falls, Manchester. Bellows Falls, Lewiston, Me., Oswego, Paterson, Augusta, Ga., Minneapolis, Rochester and Lockport combined.

The method of using the power is to be the same as that in operation upon the hydraulic canal.

The tunnel is to be of a horseshoe section, having a capacity equal to a circle of twenty-five feet in diameter, extending through the solid rock from the water level below the falls to the river above the cataract, a distance of one mile. From this point the tunnel is to continue parallel to the shore of the river one and one half miles more at an average depth of 160 feet below the surface, and about 400 feet from the river, with which it will be connected by surface conduits. The tunnel is used as a tail race, and the great length is necessary to avoid marring the scenery. Plans have been made for a 120,000 horse-power plant.

Crossing over into Ontario, we find that a scheme is

contemplated to utilize the Canadian Falls. The plan is wholly different from that on the American side, and no long tunnel is necessary. Mr. Ferranti has this work in hand.

The papers have discussed a scheme for transmitting power from Niagara to the World's Fair, which involves a distance of 475 miles, which is more than four times that separating Lauffen and Frankfort. Eighty thousand volts is the suggested voltage.

California capitalists were among the first to recognize the value of electrical transmission for mining purposes. A power plant was built by the American River syndicate of El Dorado County, more than two years ago, which utilized the water-power of Rock Creek. The plant consists of an eight-foot Pelton wheel, running under a head of 110 feet with a five and one-half inch nozzle. It has a maxmium capacity of 130 horse-power. The current generated is used at the mills, situated some two miles distant; three centrifugal rolling mills, and a ten-stamp battery and rock breaker being operated. The potential used is 100 volts, and seventy-five per cent. of the power generated is available for duty at the mill. The entire works are further lighted by incandescent lamps. The mills are handling an average of 4,000 pounds of ore per month, and a saving of some sixty per cent. over the former method has been effected.

Other plants are located at Grove Mine in Amador County, Cal., and at the Cœur d'Alene Company's works of Idaho.

Probably in the before-mentioned Lauffen-Frankfort installation, the highest potential yet attempted on a large scale was utilized. There a voltage up to 30,000 volts was obtained, and the insulators were found able to stand the pressure.

It is figured that if an insulation can be made capable of standing 1,000,000 volts, over 30,000 horse-power can be transmitted 500 miles with a 0000 wire with a loss of less than one-half per cent. One ampère at this pressure would transmit 1,250 horse-power.

The application of electricity to steam railroad propulsion is a problem that is now upon us. Since the first of this year the engineers of five of our largest railroad systems have been in consultation with the electric companies in reference to this matter.

We have in course of construction a thirty-two-ton locomotive that can easily run seventy miles an hour, and before the end of the year the power and speed of the electric locomotive will be a demonstrated fact and no longer a theory. It will be easy to demonstrate its economy in many places where it can advantageously replace the steam locomotive; but for long distance runs it cannot at present compete with steam except under unusually favorable conditions; as for example, where there are a succession of water-powers that can be utilized as sources of energy. At present we can only speak of what is to be done. Next year I trust we can point to what has been done.

The application of electric-power to street-car propulsion comes nearer to the masses and is of more direct benefit to mankind than any other application at the present time. It is almost universally acknowledged that the vexed question of "rapid transit" can only be solved by the use of the electric motor. The development in this respect has been enormous.

There are in the United States, according to the census of 1890, sixteen cities of over 200,000 population. There are electric railways in fourteen of these, or in over eighty-seven per cent. There are forty-two cities of from 50,000 to 200,000 population and of these forty-one, or over ninety-seven and one-half per cent. are supplied with electric railways. There are 450 electric railways in the United States at the present time and over 6,400 cars operated by electric-power, and sixty-two more roads are being constructed.

Notwithstanding the constant newspaper statements as to the dangers of the trolley system, we have yet to find a single authenticated instance of death caused by the 500-volt railway current carried in the trolley wires. We have at our office many newspaper clippings alleging

such cases, but upon investigation every one is found to be incorrect, the death, where there is any fatal result, arising from other causes. For example, a workman in Bangor, Me., was painting a building and short circuited an alternating incandescent current through his body, falling from the building and being picked up dead. In the newspapers his death was caused by the trolley, though as a matter of fact he was never near the trolley wire; never came in contact with it. These facts were certified to by the coroner. I was told of a man who fell from a building forty feet to the ground. He struck the trolley wire in such a way as to produce a short circuit which slightly burned his leg. He stated that the trolley wire in all probability saved his life, as it broke his fall.

On the 16th of this month, the Cambridge line of the West End Company in Boston had been in operation just three years. Since February 16, 1889, there have been many additions made to the electrical equipment of the West End Road; until now they have 120 miles equipped electrically and over 300 electric cars in operation.

Last year 119,264,401 passengers were carried on these West End cars, and not one single individual has ever been killed or seriously injured by the trolley current. There have been accidents—very sad accidents. Men, women and children have been run over and killed, but such accidents happen on every road whatever the motive-power, and it is a striking and most significant fact that the insurance companies which insure street railways against loss by accidents find relatively more accidents on horse-car lines than on cable roads, and more accidents on cable roads than on electric roads.

OLEOMARGARIN.

By Prof. G. C. Caldwell, Cornell University, Ithaca, N. Y.

[*A lecture delivered before the Franklin Institute, January 18, 1892.*]

One of the most interesting groups of chemical compounds, and one of the most important in the arts, is the fatty acid series, so-called because many of its members are attained from fats. These acids, twenty in number, are constructed on the same plan, all of them containing two atoms of oxygen and each differing from its predecessor by CH_2 or twice or three times that; all of them have twice as many atoms of hydrogen as of carbon. If we compare acids that are contiguous to one another in the series, we find such close resemblance between them in properties, that it is often very difficult to separate them completely from one another by either physical or chemical methods; but as the composition of these acids gradually changes with each increment of CH_2, the properties change also, so that comparing acids widely apart in the series we find very different properties. Formic acid, $HCHO_2$, and acetic acid, $HC_2H_3O_2$, are easily soluble in water, very sour to the taste, quite corrosive on the skin when very concentrated and convertible into vapor without decomposition, so that they can be distilled. Palmitic and stearic acids, $HC_{16}H_{31}O_2$ and $HC_{18}H_{35}O_2$, also closely resemble each other, but differ strikingly from formic and acetic acids. They are quite insoluble in water, have no sour taste, cannot be distilled without decomposition and have no action on the skin, no matter how concentrated they may be.

Out of this series of acids, I select six as possessing special interest in connection with the subject upon which I have chosen to speak to you this evening. Four of these, butyric, caproic, caprylic and capric, are near together in one part of the series; and two, palmitic and stearic, are near together in another part

Intimately associated with both of these groups is an acid of another series, oleic acid.

As is known to all chemists, when any natural fat or fatty oil is heated with soda or potash, and this product is heated with a strong acid, a mixture of fatty acids is obtained, very rarely, if at all any one fatty acid; glycerine is produced in the same operation. Corresponding to each fatty acid is a body called a glyceride; and it is the mixture of these glycerides that constitutes the original fat from which the mixture of fatty acids is produced. The glyceride of butyric acid is called butyrin, of caproic acid, caproin; of palmitic acid, palmitin, and so on.

Nearly all the ordinary natural fats and fatty oils consist essentially of three glycerides, palmatin, stearin and olein. The differences in odor and taste by which they are distinguishable from one another are due to minute quantities of other substances which they contain, and which are also associated with them in their natural, or in their prepared condition. Castor oil, olive oil, tallow and lard are unmistakably different to our senses of taste and smell; but all of them alike consist essentially of palmitin, stearin and olein, this mixture being scented and flavored by the foreign substances just mentioned.

There is an important difference between the fat in milk and some other fats, on the one hand, and the fat of tallow, lard and palm nut oil on the other hand; a distinction all the more interesting since it exists between the fat that is deposited on the carcass, and that which is secreted in the milk of the same animal. Butter and tallow are mostly but mixtures of olein, palmatin and stearin, the same three glycerides that are so widely distributed in the fats everywhere; but butter fat contains, besides, the four other glycerides, butyrin, caproin, caprylin and caprin; but since even these glycerides when purified are as tasteless and odorless as any of the others, none of the odor or flavor of butter can be credited to them.

This being the case, then, it is only natural that the attempt should be made to give a butter flavor and aroma to the more abundant and much cheaper fats of the animal

carcass; it is only a question of transforming the carcass fat into one of the same consistency as that of butter at ordinary temperatures, removing its characteristic flavor, and substituting therefor the butter flavor. The first change is easy enough, consisting as it does simply in taking out a certain proportion of the less fusible stearin and palmitin, so as to leave a residue with a larger proportion of olein, and therefore softer at common temperatures, as butter is softer than tallow; since this odor and flavor are largely due to soluble and volatile foreign substances, steaming and washing the fat will leave a sufficiently odorless and tasteless product as a basis for receiving the desired butter flavor. It is plain that the available quantity of this product from the carcass fat is much larger than the available quantity of the material like which it is to be flavored, the butter fat of milk. How then shall this flavor be imparted?

We know quite well that when it comes to giving the flavor of lemon, strawberry or raspberry to ice cream or cake, not even the shadow of the fruit need be cast over the material to be thus flavored; much less need any of its substance be incorporated with the cream or dough; a chemist in his laboratory can manufacture at least many of these flavoring essences more cheaply than they can be made from the fruits. But I am not aware that any essence of cow's butter has ever yet been prepared. A clean mixture of olein, stearin and palmitin, no matter how carefully the proportions of these three ingredients might be adjusted to secure the right consistency, no matter how deftly colored, would never pass for butter, even with the least fastidious. Therefore, the amount of salable artificial butter that can be made from this olemargarin is limited by the degree of thinness with which real butter fat with its butter flavor can be distributed through it, and produce a resemblance to butter.

Just here a few words in explanation of the terms oleomargarin, margarin and butterin may well be given. In the list of fatty acids margaric acid comes between palmitic and stearic. Originally it was believed that the three glycerides,

palmitin, margarin and stearin, together, made up the less fusible part of all fats; and that a mixture of the four fatty acids, oleic, palmitic, margaric and stearic was obtained, when these fats were saponified and the soap was decomposed by a strong acid. In fact, the three acids, palmitic, margaric and stearic, were apparently separated from one another out of this mixture of acids by repeated re-crystallization; the supposed margaric acid thus obtained refused to change any further by continued treatment of the same kind as that by which it was made; and, as its composition, melting point, specific gravity and solubility were such as might be expected of any acid standing midway between palmitic and stearic acids, no one doubted the existence of this glyceride in these fats. Heintz, in 1852, declared that this was all a mistake, that this supposed margaric acid was only a mixture of palmitic and stearic acids, and that every specimen of so-called margaric acid prepared from fats could be resolved by his method of fractional precipitation into palmitic and stearic acids. Five years later he prepared the real margaric acid in a pure state, by chemical action on spermaceti, possessing all the properties that margaric acid should possess, including, in addition to what the old acid did not possess, a persistent obstinacy against being split up into palmitic and stearic acids.

But while margarin does not occur in natural fats, its name still remains associated with the less fusible part of animal and vegetable fats, although this mixture is one of palmitin and stearin only; and since olein from the other series of glycerides is always associated with palmitin and stearin in these fats, we have the familiar name oleomargarin for this manufactured product; the same name could just as appropriately be given to many other fats, and just as incorrectly also; but it has come to be a trade name, the meaning of which is understood by everybody. First, when this oleomargarin, or oleo oil as it is sometimes called, is churned with milk and water, do we have the real artificial butter, or butterin.

The name of a Frenchman, Hyppolyte Mége, or Mége-Mouries, is most prominently associated with the early

history of this new food product. The statement is generally made that he was requested by the French government, and one writer says by Napoleon III himself, to make the experiments that led to his invention, for the express purpose of discovering a substitute for butter that would be cheap enough to come within the reach of the poorer classes and would also keep better than butter and thus be adapted for use in the navy. In 1873, he took out his first patent in this country, which was essentially as follows: The crude fat was first disintegrated between rollers, then heated about 103° F., to separate it from the tissues, or to *render* it, technically speaking; during this rendering, he added two litres of gastric juice for every 100 pounds of the fat; this gastric juice was obtained by macerating half of the stomach of a pig or a sheep with three litres of water containing thirty grammes of dicalcic phosphate; salt was also added to facilitate the separation from the tissue; the fat was then kept for a long time at a temperature of about 98° F., to allow the less fusible glycerides to crystallize out partially, after which they were separated from the more fusible part by heavy pressure in cloth bags; that which remained in the bags was called the stearin, and that which passed through the oleomargarin. This, the patentee says, is a fatty matter with a very good taste that may replace butter as used in the kitchen.

To make a more perfect butter, he mixes this first product, as it comes from the press, very thoroughly with ten per cent. of its weight of milk and cream and at a temperature of about 71° F. The mixture is cooled and worked between rollers to give it the consistency of natural butter. He has also found it expedient to mix with the milk or cream, one-fiftieth of its weight of mammary tissue from the udder of a cow, chopped very fine, one one-hundredth of sodium carbonate, and some coloring material.

This patent was followed by nearly fifty others, relating to the manufacture of oleomargarin, or some similar product, or artificial butter. Some of the new names introduced are curious; such as butteroid, oleoid, creamine, oxyline; this last name is very suggestive of the manufac-

ture of the substance from oxen. There are curious processes too in some of these patents as well as names; in one, the use of salt, saltpetre, borax, salicylic acid and benzoic acid is covered; in another, that of swine fat, cotton seed oil, slippery elm bark, and beef stearin; in another, nitric acid; in another, lard, beef suet, butter, glycerine, salt, water and coloring matter.

After all this effort of the inventors for something new in materials used or methods of manipulation followed, the process has simmered down to a very simple one, which is in reality only a part, and almost unchanged, of Mége's original process. The fat, said to be only the caul fat, and possibly so in all the large manufactories, is washed in cold water, surrounded with ice till the animal heat is removed, cut up fine, heated to from 120° to 150° F., allowed to stand till the fat is separated clearly from the tissue, then kept in wooden tanks for from twenty-four to thirty-six hours in a warm room, at such a temperature as will favor the crystallizing out of the largest part of the stearin, together with a little of the palmitin; then, in hydraulic presses in the same room, the solid fat is separated from the liquid, or the "oleo oil." Another product is prepared from lard in a similar manner, except that no stearin is removed from it, and this goes by the technical name of "neutral." From this oleo oil and neutral the oleomargarin and butterin are made, more oleo being put in if the product is to go to a cold climate, more neutral if to a warm one; the proper mixture of the two is churned in a steam-jacketed vessel, with about forty-eight gallons of milk to every 2,000 pounds of fat; it is stated that cream is sometimes used in the place of milk; butter coloring or annato is used unless forbidden by law. The churned product is suddenly cooled by allowing it to run out on to ice or cold water, then washed, salted and worked as butter usually is. The use of lard is comparatively recent, and it is interesting to notice that the first manufacturers of artificial butter were very indignant when it was attempted in the West to palm off a product from lard as oleomargarin; they used about the same contemptuous expressions concerning this

as the dairymen now use so freely when speaking of the oleomargarin. Such is the substance of the simple process for the manufacture of artificial butter in its various forms.

As to the quality of the product. In the first place, it keeps well if made from clean materials; because, as is claimed, of the absence of the lower glycerides of the series, especially butyrin, and also, as I think may be safely said, because more free from nitrogeneous matters in which the tendency to putrefy is very strong. A second important quality is such close resemblance to genuine butter of fair quality, that often only experts can distinguish one from the other. Amusing stories are told, illustrative of this close resemblance, many of them, perhaps, only partially true, yet all of them possible. It is claimed that samples of artificial butter have carried off prizes at fairs, for first-class genuine butter. One manufacturer certified before a legislative committee in my own State that he had in many instances put the artificial product before his friends by the side of dollar-a-pound butter or fifty-cent butter, and they were unable to detect the difference. I myself gave to a friend keeping an excellent boarding table, a small box of the artificial butter that I carried away with me from one of the manufactories in New York. The usual butter supply of this table was always unusually fine and the boarders were correspondingly critical; but they did not notice anything unusual in what was on the table at that meal. The story is told of a Board of Managers of the Agricultural Society of this State, that a print and a roll of oleomargarin butter were sent to them, with the inquiry "Which is butter;" at first they pronounced the roll to be butter; then they said the print was butter; then they tried some one of the simple tests that have been put forth from time to time for detecting oleomargarin, but which are usually worthless, and they finally concluded that both the print and the roll were oleomargarin, as they really were; but they closed their report with this question, "Are we right?"

But by far the most important question concerning the oleomargarin as food is that of its wholesomeness, as com-

pared with butter. The answer to this question turns on two points.

(1) The quality of the materials used in its manufacture.

(2) Its digestibility when properly made.

It may be safely said that no other food product has been so much discussed in respect to its healthfulness.

In the first place, what bearing has the quality of the materials used in the manufacture of oleomargarin on its wholesomeness? Concerning this, most damaging statements have been made; especially was this the case at the very beginning of the oleomargarin war. Many were doubtless suggested by some of the patents that were issued at this time; the purpose of some of these patents was openly stated to be to make foul fats clean, at least so far as taste and odor might serve to detect foulness. Here are a few of these statements, made or endorsed even in legislative halls. "All kinds of filthy fats are used." "Animals dying from all kinds of diseases are utilized." "Artificial butter is the compound of diseased hogs and dead dogs. It is so manufactured that it is a poison, for it has collected in it germs of all the diseases that infest animals." "The city scavenger butters your bread and his reeking hand decks your table." "St. Louis manufactures lardine, a compound of hog fat and decayed vegetable matter; horses dying with glanders or pneumonia, and dogs dying with rabies are carted to the boiling establishment where the fat is extracted and shipped away. What assurance have we that it does not find its way to the butterin factory? None." "This article of the slaughter pen and apothecary shop, the product from a charnel house run through a chemical laboratory, carrier of death and the grave." "A compounded article, mainly composed of ingredients that are not food products, or those of an inferior deleterious, and nauseating kind—refuse and offal which have served their purposes, and been relegated by the decent sense of mankind to the dung heap." The names of Congressmen making these statements are given in the document from which these extracts were made. A prominent agricultural writer of my own State wrote, "That there is nothing in the fat line

so filthy and disgusting that it cannot be deodorized and incorporated into the stuff." A Boston butter dealer stated, to the Congressional Committee, that "Every conceivable grease of the filthiest kind in our country is manufactured into imitation butter, and sold to consumers."

We all know that a good many things are said for effect by our legislators as well as by others that will not bear close examination into their correctness. If even the half of these statements were true, then certainly a committee of the New York Legislature, intent on making in its report the very worst possible showing against oleomargarin, in support of a very stringent and prohibitory law, could have obtained similar statements from some of the numerous witnesses cited before it; but a careful examination of the whole printed report of 276 pages, reveals no worse assertion than this, that not merely the caul fat, or that on the membrane investing the viscera, is used, but also that on the intestines themselves; and this witness affirms that this fat was in the vats mixed up with some of the excrementitious matters naturally associated with fat in that condition; but in the same report the manager of this factory testifies that not all of the fat received at the establishment is used for oleo, since they manufacture tallow also; and that but a very little of the intestines remains attached to that part of the fat used for oleo; the first witness did not testify that he actually saw the foul fat that he described worked into the oleo oil. No sound proof is anywhere given that such extravagant statements as those which I have quoted are founded on facts, or were anything more than conjectures or guesses.

But oleomargarin has been no less bitterly and extravagantly attacked on another line, namely, with reference to what has been found in it especially by microscopic examinations. Prof. Michels, of New York, in 1878, stated that he had found cells of a suspicious character, and fragments of muscle and tissue in some of the samples that he examined; these, however, he acknowledged came from the chopped stomach then used according to the original Mége patent; but he affirmed that trichinæ might get into the butter in

this way, and that the heat to which the fat was subjected in the course of the rendering and the crystallization would not be high enough to kill them.

In 1880, a Professor Piper gave in a Chicago daily paper some startling drawings of what he had seen in some samples of oleomargarin butter, under the microscope; shreds of animal tissues, spores, and a form often found by him in foul water; and in another paper he gave figures of actual tape-worm eggs, and by the side of these very similar forms from oleomargarin. Passing on to a later date, when the addition of chopped stomachs and mammary glands had been entirely given up, very little is reported of observations of this kind. A Professor Nachtrieb is quoted as finding in a sample of butterin parasites that are present in the rectum of swine, and in the evacution of patients suffering from chronic diarrhœa; but without further knowledge as to the reliability of this professor as a microscopist, one should give little weight to such a startling statement. Two samples of artificial butter out of ten were reported by an official of the Department of Agriculture as being full of fungi and their spores; but as all of these were also reported as being in a bad condition even for samples of butterin, such an observation furnishes no reliable evidence as to the usual quality of the substance; further, the reputation of this observer was not of the best.

Before leaving this part of my subject, I cannot forbear quoting one or two more of those wonderful Congressional statements: "The best samples had many kinds of living organisms in them, with masses of dead mould, bits of cellulose, various colored particles, shreds of hair, bristles, etc., while other samples teemed with life; doubtful portions of worms were also noticed." Again, "There were in every specmien more or less foreign substances, a variety of vegetable and animal life. Among these were corpuscles from a cockroach, small bits of claws, the blood corpuscles of sheep, the egg of a tape-worm, a portion of a worm, a dead hydra-viridis, portions of muscular fibre, fatty cells and eggs from some small parasite;" and all this, I am ashamed to say, said by a member from my own State. You

will notice that these two statements begin, the one with the words "the best specimens," the other with "every specimen." That any such observations could have been made on the best samples of oleomargarin, or even on all samples collected at any given time, is, I am safe in affirming, in the highest degree improbable, not to say entirely out of the question, even at the time when chopped pigs' stomachs and mammary glands were worked into the product; and that they could have been made, at or about the time when these statements were made, I consider quite impossible, such addition having been then long given up.

The answer to the question as to the wholesomeness of oleomargarin must then be sought on other lines of inquiry. Fats as such are not unwholesome when not eaten in excess. We need then only to consider whether one fat, clean oleomargarin, is as wholesome as another fat, butter, and we will consider first their comparative digestibility. By far the best statement of the case in this respect, it may be said, against oleomargarin, is to be found in the second annual report of the New York State Dairy Commissioner for the year 1885, by Dr. R. D. Clark, chemist of the commissioner. Many authorities are there quoted to the effect that butter is more digestible and wholesome than lard or other natural fats; and this difference is attributed to the more complex composition of the former, and especially to its butyrin. The effect of this substance is supposed to be due to the ease with which it breaks up into fatty acid and glycerin. Saponification is thus facilitated and the soap formed in its turn favors the digestion of the other fats of the butter. The digestion of the fats consists partly of this saponification, and partly of their conversion into an emulsion. Dr. Clark performed some emulsionizing experiments with different fats, and the pancreatic juice, which is the chief emulsionizing agent of the digestive liquids. Next to cod liver oil, butter gave the finest emulsion in twelve hours; while oleomargarin still had many large globules left unchanged. It is fair to suppose that the finer the emulsion and the more quickly it is made, the more readily the fat will be resorbed assimilated and taken into the circulation, and that easy

saponification will also favor digestion. Dr. Clark also proved that while butter melts to a clear limpid liquid in thirty-five minutes, at 100° F., the oleomargarin was but slightly changed; even after five hours the latter was still only in a semi-solid condition; this property of oleo butter is certainly not favorable to its digestion. Thus a very good case is made out by Dr. Clark, to the effect that oleomargarin is in all probability somewhat less digestible than butter. This view is supported by the results obtained by A. Mayer in a comparative test of the proportion of fat assimilated by a man and a boy, using butter of the ordinary kind for three days, and then oleomargarin for the same period; the difference was slightly in favor of the butter; but so slight that the writer considered that it might be neglected, except in the case of invalids or very young children. In France, the first opinion of medical men in 1872 as to the digestibility of oleomargarin was not unfavorable, but eight years later it was pronounced against in the Paris Academy of Medicine, the statement being that it could not replace good butter, because, on account of the higher percentage of fatty acids it emulsionized less easily and was therefore less easily absorbed; but I can find no account of any actual digesting experiments in support of this conclusion, like those of Mayer's just quoted, and which are of much more account than any theorizing.

The question of the occurrence of germs of disease in oleomargarin is of such great importance, that it needs some further consideration. The possibility of their occurrence there cannot be denied; and it must be allowed that the heat applied in any stage of the manufacture of the oleomargarin is not sufficient to kill these germs if present. Dr. Clark gives as diseases that may be communicated from animals to man, consumption, anthrax, trichinosis, tape worm, glanders, foot and mouth disease, cow pox, hydrophobia, etc.; the etc. implies that there are still others; but the list is fearful enough as it is. Now, what evidence is there that any of these disease germs are in oleomargarin? Granted that they may be there; but have they ever been found there by reliable observers? Any evidence

of this, sound and satisfactory, would be the most damaging that could possibly be produced against this food product. The observations, quoted in an earlier part of the lecture as made by Piper and Nachtrieb, utterly lack confirmation by others; no similar observations have ever been reported since. Dr. Clark, in his summary, does not even refer to them. It may therefore safely be affirmed that there is no evidence whatever that in the oleomargarin of later years, from 1885 up to the present time, any germs of disease exist.

But good evidence of the communication of any of these diseases to man by the use of oleomargarin would be no less fatal to this food product. Members of Congress assert that its consumption "Leads to insanity, Bright's disease and ailments that undermine the strongest constitution;" that "It is freighted with disease, freighted with death; that it spreads disease and death throughout the country." Dr. Clark, above quoted, in response to the demand for cases of illness caused by oleomargarin, can only say that "We have seen many cases of sickness, much of it dyspepsia, during the period in which bogus butter was so freely sold without restriction, for which we have been unable to assign any cause; this cause may have been the use of artificial butter; but the deceptive manner in which it has been handled has prevented physicians from ascertaining its effects; consequently we must judge by its qualities." This is a confession that up to that time, 1886, and only shortly after a time when it was claimed that 20,000,000 pounds per annum were made, and mostly used in New York and England, no case of disease nor any general specific form of disease could be pointed out as due even in the most indirect manner to the use of this food product. A widely quoted statement to the effect that the physicians of Chicago attributed the epidemic of winter cholera to the extended use of butterin in that city, into the composition of which lard entered largely, may be taken for what it is worth, as an exception to this statement of mine. I cannot verify or dispute it.

The chairman of the New York Legislative Committee,

from which emanated the present stringent prohibitory law of that State, in his report on the committee's investigations, could only say in reference to the wholesomeness of oleomargarin, that sickness of various kinds may result from its use, communicated by the germs of disease that have been found in samples of it; but nowhere in the report of the committee is any evidence adduced of the occurrence of these germs. Even a single case of disease unmistakably attributable to oleomargarin would have been invaluable in promoting the passage of the desired law; but he could not produce it; and in another place in the report he frankly allows that "There is evidence on both sides as to its wholesomeness; time and further investigation may be needed in order to establish a satisfactory solution of the question of trichinæ, animalcules or germs of disease in raw animal fats and their tissues. Meanwhile, however, there is well-grounded suspicion of them." Time there has been, years of it, since that report was made public. The prohibitory law was passed; but no further investigation has been reported on the trichinæ and germ question; and the danger of disease from this cause must be regarded as unproven.

An interesting incident bearing on this matter has very recently come to my knowledge. At an asylum for blind children, in Louisville, Ky., where good butter had been supplied, good oleomargarin butter was substituted. No notice was given of the change, and even if the appearance of the substitute would have betrayed it, the blind children could not have seen it. There was no evidence that they were in any way conscious of the change; but it was observed that they gradually ate less and less of the new butter and finally they declined it altogether. No bad effect on their health could be discerned. They made no complaint in answer to the inquiry as to the reason for not eating the butter other than that they did not care for it. It was as if it did not adapt itself to any need of the system. This certainly must be allowed to count against the complete fitness of oleomargarin as a substitute for butter.

Beyond what I have given you in what has gone before,

I find nothing more in the literature of this subject for the past twenty years that relates to the question of the danger to health in the use of oleomargarin, except numerous statements by scientific men of eminence in this and other countries. Morton, President of Stevens Institute; Chandler, of Columbia College, for so many years President of the New York City Board of Health; Johnson and Brewer of Yale, both well known by farmers throughout the country for the good work they have done in behalf of agriculture; Goessman, now and for many years past, Director of the Massachusetts Agricultural Experiment Station; Atwater, of Connecticut, so well known for his writings on food products; Armsby, Director of the Pennsylvania Experiment Station; Alvord, most prominently identified with the interests of farmers for many years, and now Director of the Maryland Experiment Station, all have spoken or written in favor of oleomargarin as a food product. It has required the courage of their convictions for many of these men to utter their opinions; and they have in many cases had only the comfort of a clear conscience to offset the abuse of the agricultural press that has been heaped upon them. Abroad, I would mention particularly Lyon Playfair, one of the most distinguished chemists and sanitary authorities of England. In his place as Member of Parliament, he spoke in a very different strain from that indulged in by some of our Congressmen, when he said, "As to the relative wholesomeness of oleomargarin and butter, I do not think there is anything to choose between them. Certainly, rancid oleomargarin is a nasty and unwholesome compound; but not any more so than nasty and rancid butter, which abounds in so many markets. Both are unfit for human food, although both may be purified by well-known processes." I would like to quote more from this admirable speech, but lack of time forbids.

Finally, allow me to call your attention to the remarkable absence of any reference to this food product, by the most active and efficient State Boards of Health in this country. If there were such terrible dangers lurking in oleomargarin, as has been so many times asserted, surely these Boards of

Health have seriously failed in the discharge of their duty in giving so little attention as they have to the matter. A careful examination of the files of such reports as are in our University library fails to disclose any allusions of any importance whatever to the subject. Some of these States have prohibitory laws, and their reports extend back from five to fifteen years.

The whole question of the wholesomeness of oleomargarin as food is summed up in my own mind about in this wise: When properly made from fresh and clean materials it differs but slightly in healthfulness from butter; and this difference is only on account of its somewhat less easy digestibility; that dyspepsia, which has been attributed to it, is likely to be due to a far greater extent to other causes than this, even among those who, because of its cheapness as compared with butter, would be likely to use it largely; that it is possible that it may be made from such unsuitable materials that it will contain germs of disease, and that disease might thus be communicated to man; but that there is no positive proof that it is now made of such materials, or ever has been, or that any disease has ever been communicated to man by its use; but that the possibility exists, all the same, and the only way to make it of no effect is by careful inspection of the process of manufacture by capable officials.

To my statement that probably no other food product has been so much discussed with reference to its wholesomeness, I may also add that none has been so much specially legislated upon as this. Let us consider what is the present condition of this legislation.

New York being a great dairy State, and also, in the beginning, the great centre of the manufacture of oleomargarin, was naturally one of the States in which special legislation began earliest. Two enactments in 1882 prohibited, (1) the coloring of the product to make it resemble butter, or the sale of any such colored product; and (2) required that all packages containing any such imitation of butter or cheese be plainly labelled. In 1884, the manufacture and sale of such imitation were forbidden in a

special section of a general dairy law. This was pronounced unconstitutional by the Court of Appeals; but another slightly different enactment in the following year was allowed to stand. The constitutionality of this final enactment was decided on this ground: that when a product of manufacture is turned out so closely resembling some other product of which the manufacture is already established, as not to be distinguishable from it by the senses, and is made for sale in the place of that substance, it is constitutional to prohibit the manufacture and sale of it. But if it is turned out in some different form, as, for instance, uncolored, then its manufacture and sale cannot be prohibited, except on plain grounds of injury to the health of the community. At the close of 1885, Maine, Michigan, Minnesota, Missouri, New Jersey, Pennsylvania and Wisconsin, besides New York, had laws prohibiting the manufacture and sale of oleomargarin or any kind of artificial butter made from other fats; and New Hampshire had a law that was practically prohibitory, requiring that all such imitation of butter should be colored pink. California, Colorado, Connecticut, Delaware, Ohio, Oregon, Rhode Island, Tennessee, Vermont and West Virginia had simply regulative laws, providing that the substance shall be sold under its own name.

At the close of the year ending June 30, 1891, Maryland had been added to the list of prohibitory States, and Minnesota, Vermont and West Virginia had joined company with New Hampshire in requiring the pink coloration of the artificial butter, while New Jersey, Massachusetts, and Ohio prohibited the sale of it only if colored in imitation of butter. Of the other States, Arkansas, Kentucky, North Carolina, Tennessee, Utah and Washington had no enactments in regard to the matter. The remainder of the States, twenty-five in number, merely required that it should be sold under its own name and not as genuine butter. Abroad the laws are all regulative, and not prohibitory.

In 1886, the national law was passed, under the title of "An act defining butter, also imposing a tax upon and regulating the manufacture, sale and importation of oleo-

margarin." This act required every manufacturer to pay \$600 for a license fee; every wholesale dealer not a manufacturer, to pay a license fee of \$480; and every retail dealer selling in quantities less than ten pounds, to pay a fee of \$48; and that every pound sold shall pay a tax of two cents. It was first attempted to make this ten cents, but by reduction to the lower figure, the enactment was saved from being practically prohibitory. President Cleveland approved the measure on the ground that Congress is justified in making oleomargarin a subject of internal taxation; that Congress may clearly levy such taxes as will confer incidental advantages on the people; and that no industry is better entitled to such incidental advantages as may follow this legislation than our farming interests; and that the quality of the article will come under more strict scrutiny so that only a good and clean product will be sold; and, finally, the product will be sold under its own name and fraud and imposition will thereby be suppressed.

Recalling to mind some of the extravagant statements in Congress in support of this measure, or especially of the ten-cent clause of it, the comment on it as passed by a prominent agricultural paper is appropriate: "That if oleo is as bad as it has been painted, the new law will make the Government a party to the crime of permitting an unwholesome article and its action is, therefore, simply and purely a compromise with the devil." I wonder how many actually believed that it was as bad as it was painted?

What has been the motive in the passage of the sundry enactments concerning oleomargarin? Was it for the preservation of the public health, or for the preservation of another industry? The speech of the chairman of the committee, above referred to, in which the passage of a restrictive bill was asked for, covered twenty-eight pages of print of which only four refer to the public health. The great burden of the speech is the harm that is being done to the dairy interest by the secret trade in oleomargarin. Such statements as these are prominent. "A great and important industry of this commonwealth, and of the nation of which we are a part, is imperilled. The industry imperilled is th

American dairy." "The dairy to-day lies prostrate at the feet of this new butter king." Over against all this and more on this phase of the question, all that was said in the speech concerning the question of wholesomeness, was uncertain in tone, and wisely so, since so little proof could be adduced of the danger to health by its consumption.

In 1884, when the prohibitory bill was before the Senate, the burden of the argument for it was again the pecuniary loss caused to the dairy, of from $5,000,000 to $10,000,000 per annum; the sanitary side of the question was just touched upon, reference being specially made to the use of nitric acid in the rendering of the lard, which chemical, it was said, is a poison; but the committee could only state in general terms, an opinion that the oleomargarin is likely to be unwholesome.

In reference to the prohibitory law of Pennsylvania, the Supreme Court affirmed its constitutionality, saying that "The manufacture and keeping of an article may alike be prohibited by the legislature, if in their judgment the protection of the public from injury and fraud requires it." "The fact that the prohibited article may be innocuous is irrelevant; the sale of a mixture of pure water and milk has been prohibited." Here again the question of the public health is not taken into account. Of the same character was the decision of the Missouri Court of Appeals, on the constitutionality of the prohibitory law there; nothing was said about the public health. In the case of the almost frantic appeals sent out from Washington at the time that the practically prohibitory bill with the ten-cent clause was pending, it was the farmers of the country who were called upon to work upon their representatives directly, and upon the Senate through their respective legislatures, to secure the sufficient support of the bill in Congress.

So I might go on, adducing other evidence in support of my contention that the consideration of the public health has had very little weight in the minds of the ardent advocates of these prohibitory laws, or of any other legislation on oleomargarin, and that the money question was the real one at issue. Not a few protests have appeared from time

to time against such proscriptive legislation, even in the agricultural press. One of the most prominent dairy writers in the country, writing before the passage of these laws, said "There is no law and there can be no law to prevent its sale for what it is." Another, who, while he lived was esteemed as among the highest authorities in the country on dairying, when asked if the manufacture of oleomargarin should be prohibited by law, answered: "By no means. Its manufacture is as legitimate as that of butter. Its manufacture is actually a blessing. On the one hand it is suppressing the lower grades of butter; and on the other hand, it makes the finer brands of creamery butter more sought after. There is nothing for the dairymen to fear in it. Their safety can be insured by improving their butter product."

What has been the effect of this stringent legislation on the extent to which the product is manufactured, on its quality, and on the interests of the class of producers for whose benefit the laws have been enacted? It would naturally be expected that the first effect would be one of marked depression in the quantity made in some States, and of increase in others where no laws were made. It was stated in the New York Legislature by the chairman of the committee already many times referred to, that in 1888, 20,000,000 pounds were made in that State alone. This estimate is confessedly to a large extent guesswork. As to the total production in the country at any time previous to the passage of the national law, there appear to be no reliable data. It was wildly stated to be 200,000,000 pounds; it was admitted by those not interested in making the estimate excessively high, that the amount may have been half as great. For the fiscal year ending June 30, 1886, it was estimated on the basis of data claimed to be reasonably sound to be about 33,000,000 pounds. In the following year it was nearly 35,000,000 pounds; in the next year, 35,664,000 pounds. During the year ending June 30, 1891, 44,000,000 pounds were produced; and the great manufacturers, Armour & Co., of Chicago, predict a still larger output for the year ending June 30, 1892.

It is interesting to see where the manufacturers are, and also where the oleomargarin is consumed, the location of the retail dealers giving us very reliable information as to this last point. Concerning all of these matters the reports of the Commissioner of Internal Revenue furnish sufficient data. In 1889, there were twenty-three manufacturers, distributed as follows: Colorado, 1; Connecticut, 6; Illinois, 7; Indiana, 1; Kansas, 2; Maryland, 1; Massachusetts, 1; Ohio, 2; Pennsylvania, 2; the last-mentioned notwithstanding her prohibitory law. The other part of the story, about where it was eaten, is somewhat startling. Of the whole number of States, only eleven were not mentioned in the list of those having retail dealers within their borders. Of these eleven only three—Delaware, Maine and Minnesota—had prohibitory laws. As to the rest, beginning with the State having the largest number of retail dealers, Illinois had 1,091; Massachusetts, 460; Connecticut, 424; Michigan, 387; Ohio, 362; Missouri, 258; Pennsylvania, 157; Kentucky, 116; then follow the other States with numbers ranging from eighty-five down to one. Two bold firms even dared to open shops for the sale of oleomargarin in my own State, in 1887, another was added in 1888, and all three were there in 1889.

But what shall be said of the condition of the matter in some of the other States with prohibitory laws? Missouri was the first to have such a law, and even you Philadelphians had in that year twenty-five dealers in your very midst, and 157 in the whole State; and you have a prohibitory law, too, that your courts have pronounced constitutional. Michigan, with her prohibitory law, also had 387 retailers of "the vile stuff," as our Dairy Commissioners are accustomed to call it; Wisconsin, another prohibitory State, had 85 dealers, and New Jersey, still another, had 75. As for New Hampshire, her 47 retail dealers who have been in operation since 1887 had probably learned how to color their oleomargarin butter such a delicate pink that it would not be noticed by the unsuspecting boarder, but still enough to comply with the law; or do they come out in bold defiance of a very natural preju-

dice against pink butter, and color it deeper than ever the brightest carnation showed.

Another interesting feature of the statistics given in the Commissioners' reports is the steady increase in the total number of retail dealers, from 2,316 in 1887–88, to 5,914 in 1890–91. In Missouri, the number increased to 627, or more than double what it was in 1889. In Pennsylvania, the number had risen to 1,100, and there were, besides, 2 manufacturers and 59 wholesale dealers. Only four States paid, in 1890–91, a larger share of the revenue on oleomargarin collected by the Government than did Pennsylvania; those States being Connecticut, Illinois, Kansas and Ohio; of this $46,000 was paid at Pittsburgh.

In New York the law is well enforced with the aid of a large appropriation and many officials. All the usual channels by which this oleomargarin is liable to enter the State are carefully watched and a few convictions are made each year. One of the discoveries thus made in 1890 was on a small island in Long Island Sound, where "the vile stuff" was found in a room used mostly for storage of rubbish—300 pounds of it packed in the bottom of an old ice chest, covered several layers deep with potato bags, and then the box itself covered with bags and old boxes. The proprietor was arrested, pleaded guilty and was fined $100.

These figures as to the consumption of this food product in the country, seem to indicate that there was not a hearty public sentiment behind the noisy clamor that urged many of these enactments on to their passage. This view of the matter is strengthened by the fact that so few of the more influential agricultural papers, and of the best writers for these papers were in favor of prohibition; at least such was the case in my own State; and it is only reasonable to suppose that they voiced the feeling of the majority of the farmers for whose supposed benefit this commotion was raised. What the best part of the press and the most intelligent part of the farmers wanted was simply a law requiring that these oleomargarin productions should be sold under their proper names; that there should be no cheating or deception, but that everything about this new business

should be open and above board. Then they would have nothing to fear from it.

As to the quality of the product now, as compared with what it was in the first years, such a comparison cannot be made with any degree of satisfaction, since we have so few reliable data, based on official inspection of the manufacture or of the product. President Cleveland gave this as one reason for his approval of the national law, that the quality of the article will come under more strict scrutiny, so that only a good and clean product will be sold. But it cannot be said that this hope is justified. In the first report of the Commissioner under the new law, the inspectors in some cases stated that they had examined into the character of the materials used at the factory, and they found everything as it should be. But since that time I find no evidence in any of the reports that any attention is given to this matter by these inspectors.

As to the effect of the legislation on oleomargarin on the the butter product, it is also very difficult to reach any satisfactory conclusion. Many assertions have been made as to the depression in prices of butter caused by the introduction of oleomargarin, and *vice versa;* but there are very few carefully prepared figures in support of this assertion. On the other hand, in 1882, a comparison was made between the prices of butter in January and July, for the five years from 1857 to 1861, inclusive, before the war, with those of the corresponding months of 1877 to 1881, inclusive, when oleomargarin was actively made and sold; the average price was three cents a pound higher in the latter period for the best butter; and in the last two years of each period, it was seven to eight cents higher, with oleo sold under very little restriction. This statement was published in that stanch agricultural paper, the *Rural New Yorker*, and commented upon as indicating little benefit to dairymen from the prohibitory law. Elgin, Ill., is claimed to be the headquarters of the finest creamery butter, selling at forty to sixty cents a pound to the consumer. In January and February, 1886, the wholesale price of butter at the factory was nearly two to five cents a pound higher than it

was in January and February, 1887; that is, a few months after the law went into effect, butter fell in price instead of rising, much to the chagrin of some speculators who bought largely for a rise.

The New York Dairy Commissioner, in his report for 1887, claims that the enforcement of the law in that State has encouraged dairymen to feed better, and produce a larger amount of butter, for which a higher wholesale price has been paid, while consumers have had to pay but little if any more, and from his figures he estimates that the net gain to the dairy producers in the United States during the two years ending November 30, 1887, was $40,000,000.

These and other statements indicating large gains for the dairy industry by the suppression or restriction of the manufacture of oleomargarin, do not seem to be borne out by the following table, taken mostly from the report of the Commissioner above-mentioned for 1889, representing the receipts and value of butter handled in New York City for nine years:

Year.	Total Amount.	Total Value.	Price Realized.
	pounds.		*cents per pound.*
1881-2	79,864,840	$23,025,295	29
1882-3	90,547,910	22,627,579	24
1883-4	88,117,170	20,342,372	23+
1884-5	93,566,850	19,502 977	21—
1885-6	93,701,520	20,925,537	22+
1886-7	93,712,480	21,357.988	23—
1887-8	95,242,360	22,065,219	23+
1888-9	108,477,260	23,386,456	21·5
1889-90	97,655,160	18,109,142	18·5

The net gain to producers whose butter was handled in New York City in the two years ending November 30, 1887, was $1,859,011; whether it is safe to estimate from this that the gain over the whole country for that period was $40,000,000 I leave for others to judge. The heavy fall in the prices realized for butter in the last two years of the seven, shows

that other causes affect this price besides competition with oleomargarin; the unsoundness of conclusions based on one set of statistics alone of the trade in one city should also be taken into account.

But the butter industry is threatened in other ways. A German chemist has found means to purify fat obtained from some tropical plants in such a way that it will keep well and can be made into an imitation of butter. A company has been formed in the Netherlands for the manufacture of this butter; and the editor of a prominent journal established for the purpose of exposing adulterations of food, called for the preparations of several articles for the table with this butter—he being a member of one of the juries of the exposition where this butter was shown. The universal judgment was that it was excellent, and should bring the highest price. The editor of the paper from which this is taken, says that one must keep a watchful eye upon this new industry in order that at least this vegetable butter cannot be used for the adulteration of genuine butter.

Further, the attention of the Department of Agriculture has very recently been called to a more serious mode of adulterating butter than by the use of either oleomargarin or the vegetable butter. A substance, called "gilt-edge butter compound" was received indirectly from the Planet Manufacturing Company, Wichita, Kan., with the statement that by taking equal parts by weight of genuine butter and of milk, or one pint of fresh milk and one pint of butter, and one gramme of this compound, two pounds of butter can be obtained. The process consists simply in making the genuine butter first somewhat soft and pliable by warming and working it so that the churn dasher will go through it, and then churning the whole together, the milk being warmed to about 100° F., and the churn scalded so as to warm that; then salt and butter color are added. The direction is given not to work the product, but to put it away into jars in a cool place to harden. On analysis it was found that the genuine butter contained about sixteen per cent. of water, while the sample of the counterfeit

butter made with this genuine butter and with milk and the gilt edge butter compound, contained almost fifty per cent. of water. It was learned on examination that this gilt-edge butter compound contained pepsin; and experiments that were made showed that this ferment gives to butter, by acting as an emulsifying agent, the property of taking up much additional water and that the rennet ferment will act in the same way. The whole process is a very inexpensive one for loading the genuine butter with a large additional quantity of water.

As a chemist, it may be expected of me to say something about the means of detecting oleomargarin in genuine butter. A complete study of the various methods for this detection occupies many lecture hours in the course to my students in chemical analysis. Very brief treatment of the subject must, therefore, suffice here. It was shown in the beginning of my lecture that the change in the properties of the fatty acids and their compounds, as we pass from one member of the series to another, is very slight; and that it is only when we compare members of the series that are widely apart that we have such wide differences as to enable us to distinguish or separate them readily—differences in the melting point, solubility, or volatility. The fact that the fat of milk contains glycerides of two groups of fatty acids, thus widely enough separated from each other to give us marked differences in solubility and volatility, comes to our aid in distinguishing the butter from nearly all other fats, both animal and vegetable; it is the one quality of butter that enables us to make use of chemical analysis in the detection of the adulteration of butter with other fats. Butyric acid and its three associates in butter are soluble in water and can be distilled without decomposition; palmitic, stearic and oleic acids are quite insoluble in water, and are completely broken up if we attempt to distil them. Therefore, we have only to get the fatty acids out of the glycerides by saponification and decomposition of the soap by a mineral acid, treat this mixture of the fatty acids with boiling water, and separate the soluble part from the insoluble by filtration, and dry and weigh what is on the filter. The

highest per cent. of these insoluble acids that is allowed to exist in genuine butter fats, on the basis of a large number of determinations that have been made, is ninety; in oleo oil, tallow, lard, cotton-seed oil, we have from ninety-three per cent. and upwards. When butyric acid and its associates are separated out by distillation in the manner already explained, we can estimate their amount by measuring the acidity in the distillate collected; this measurement being now always expressed in the number of cubic centimetres of a one-fifth normal solution of sodium hydroxide that is required to neutralize the volatile acids obtained from two and one-half or from five cubic centimetres of butter fat. This number, which we may call the Reichert number, after the name of the chemist who discovered the method, ranges for genuine butter from ten upwards for two and one-half grammes of butter fat, or twenty upwards for five grammes of fat. The highest number for oleo oil, lard or tallow is less than one, and for cotton-seed oil and cocoanut oil seven.

By these means there is not the slightest difficulty in distinguishing pure butter from pure oleo oil, or the other preparations of a similar character; nor is it difficult to distinguish butter adulterated with, perhaps, fifty per cent. of oleo oil and upwards, but the results are not sufficiently positive for adulteration with lower amounts. Furthermore since some animal oils that can be procured in quantity have been found to contain so large a proportion of these glycerides yielding volatile fatty acids, that by the addition of them to oleo oil, the Reichert number can be brought up to that for genuine butter, with little difficulty, our dependence on either of these two methods for detecting the adulteration may yet be made very insecure. For instance, porpoise jaw oil has been found to yield a fatty acid mixture by saponification, and so on, of which the Reichert number ranges from forty-six to sixty-six; it needs only that this oil shall be so refined as to deprive it of its fishy taste and odor, in order that it may be used to put chemists entirely off the scent, in the use of their analytical methods for the detection of adulteration with oleomargarin.

A multitude of simple tests have been proposed from time to time, and of such a very simple character that any one can make them with the simplest of appliances; but they have little value, being usually quite unreliable, and no conviction could ever be based on any one of them, or on all of them combined. One of these, simple in execution, though not in appliances, since it requires the use of a good microscope, depends on the fact that when a fat solidifies from a state of fusion, crystals are formed which, viewed by polarized light under the microscope, show a distinct play of colors or other very characteristic appearances. The process of manufacture of oleo oil in any of its forms involves in all cases the melting of the fat. Butter, unless exposed to unusual heat is never melted; hence, normal butter will never present this phenomenon under the microscope with polarized light, while any fat refined by the application of heat, at any time during the process of its manufacture into imitation butter, will always show it. This simple method has been severely criticised; for it has been shown that under some rarely occurring circumstances oleomargarin may possibly not exhibit the phenomenon, and that butter although perfectly genuine may have been sometime just enough warmed to be partially melted, and then it will exhibit the phenomenon described. Nevertheless this test can be and is used by the inspectors of the Internal Revenue Bureau, specially adapted microscopes being supplied to them; but it serves only to indicate suspicious cases; a sample thus indicated as suspicious is subjected to analysis before any action is taken concerning it.

To sum up what appears to me the fair position in regard to oleomargarin: It is a food product unquestionably. No legislation can rule it out of the list of food products. Taken into the system it follows the same course that butter does, is changed in the same way, if not perhaps quite so completely; is taken into the circulation, and then serves precisely the same purpose that butter does. When properly made from proper materials it is entirely harmless, except possibly when consumed as freely as butter would be by persons with weak digestive powers.

While it is claimed by manufacturers that a good artificial butter cannot be made, if fats are used that are not clean and wholesome at the start, it may not be that this is fully established. But on the other hand, it must be granted that there is no evidence that any community in which artificial butter has been used, even freely and without any official inspection or restriction, has been any the worse for its use in respect of health, either individually or collectively. These being the facts in the case it is not surprising that many regard as unjust any legislation that prohibits the manufacture or sale of this substance, whether directly, or by such ridiculous subterfuges as require it to be colored pink or any other abnormal color; the chief motive, nay almost the only real motive for this legislation being that of attempting to save another industry, working along the same line, from pecuniary damage.

On the other hand, oleomargarin is not butter; and it is wrong to sell it as butter, no matter how good the imitation may be. Probably its manufacturers and dealers have brought all this trouble on themselves in the way of prohibitive legislation, by their attempts to sell it as butter; if from the first it had been sold under its own name, I very much doubt whether any prohibitory law would have been enacted in any State. All over the civilized world, general or special laws exist, prohibiting the selling of anything for what it is not; no one denies the need or equity of these laws; their purpose is to protect honesty against dishonesty, and to give every honest man a fair chance, whether he be a seller or a buyer. When a man sells oleomargarin as butter he is violating these laws; and in proportion to the ease with which the imitation can be palmed off for what it is not, and in proportion to the value of other industries that are injured by such deceit, should be the efficiency of the means for the detection of the fraud and the severity of the penalties imposed upon it; so that the producer of the genuine article shall not need to go far out of his way for the means of defence. Therefore, laws requiring that oleomargarin shall be sold for what it is are just laws, I care not how stringent they may be.

Furthermore, there is work for Boards of Health in connection with the trade in this food product wherever it is permitted; especially should its manufacture be watched. This needs to be done at least till it has been fully established that only clean fats from animals killed in health can be used for its manufacture. The large license fee required of manufacturers throws the manufacture into comparatively few hands, and such inspection is thus rendered comparatively easy.

Under such restrictions it seems to me that the trade in this article might safely be left to itself, and that it might be a blessing to the community as a whole, in supplying at low prices a savory substitute for butter, far better in quality than most of that which the poorer classes have to eat, if they can get only genuine butter; and for those who can afford to pay for good butter, the opportunity to get it will be better, for dairymen will be obliged to make good butter if they make it at all.

PRECISION IN THE USE OF THE TUNING-FORK CHRONOGRAPH.

By Walter L. Webb, C.E.

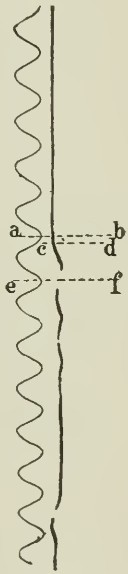
During the course of some recent experiments (in the laboratory of the College of Civil Engineering at Cornell University), in which it was necessary to determine very precisely an interval of time of about 0·72 seconds, an ordinary tuning-fork chronograph was at first used, with a cylinder of smoked paper and a tuning-fork vibrating (approximately) 100 times per second. The cylinder was turned about one-fourth inch for each vibration. The fraction of a vibration at each end of the interval was then estimated as nearly as possible to tenths of a vibration, and this gave the total time with an error perhaps not more than ·002 second. But even this error was inadmissible for the purposes of the experiment. Moreover, the smoked paper was untidy and inconvenient, and the tracings of the stylus were sometimes spoiled by accidental rubbing, even

in spite of great care in handling. And so another method was devised which gave on one set of six observations a probable error for the mean, deduced by least squares, of ·000088 second. And this did not require a larger or more costly chronograph. It needed but a few changes, made by the writer, in the ordinary chronograph that had been previously used. The first change was the substitution of white paper for smoked paper, and of pens for the styluses. The paper used was very smooth and white, but with no glaze, which enabled it to take ink freely. With a slow motion of the pen it takes ink too freely; the rapid motion here used being just right. The pens were made of very thin sheet brass rolled into conical tubes: the marking ends were filed until they would make a fine mark on the paper. The cones would hold more than enough ink for a single observation, and the tubular form prevented the spattering that would inevitably have occurred with an open pen, vibrating 100 times per second, with an amplitude of, perhaps, one-fourth inch, and containing enough ink for a line several feet long. Using ink rather than smoked paper, the paper could be handled freely without injury. And that made more easily possible the other change of method, viz: the determination of the fractions of vibrations at each end of the interval by means of the microscopes and screw of a dividing engine.

The absolute equality of the intervals of time for the different observations depended on the time required for a small body to drop a fixed height through a vertical shaft about nine feet high, made sufficiently air-tight to avoid the effect of outside currents of air, and in which the pressure, temperature and moisture were carefully determined. The beginning and end of the interval were *both* indicated by the breaking of an electric circuit and by precisely the same motion of the recording armature. Any irregularity in the action of the armature would probably happen at the end as well as at the beginning of the interval, but if there actually was any difference, it was instantly discernible by the comparative forms of the curves described by the pen of the recording armature as

it flew back on the releasing of the current. The time required for the armature to fly back was generally about ·005 second. Every precaution was taken to make every circumstance, affecting the recording of the beginning of an interval, have an equal weight and influence in the recording of the end of that interval, so that all errors were either eliminated altogether or made mutually compensating.

In the accompanying specimen of the actual work done by this process, the right hand line is the line drawn by the pen on the recording armature; where it is crossed by *c d* is the tangent point of the curve immediately below it, and shows when the current was broken and when the armature began to fly back. The paper was placed on the carriage of the dividing engine, so that the line made by the recording armature was parallel to the line of motion of the carriage. The microscope on the dividing engine magnifies about twenty-four diameters. That would cause the distance from line *a b* to line *e f* to appear as about six inches. Thus it was very easy to move the carriage until the middle cross hair in the microscope was directly over the crest of the wave as at *a b*. The reading of the screw was then taken. By moving the carriage until the tangent point (on *c d*) and the next wave crest (on *e f*) were successively under the cross hair of the microscope, the ratio of the differences of the readings easily gave the value of the partial vibration. The screw pitch is one millimetre, and there are 200 divisions on the circumference of the wheel attached to the screw. This gives about 1,250 divisions for a wave length of one-fourth inch, and so it need not be considered an unwarranted refinement to compute the ratio to the nearest hundredth. For example:



$$\left\{\begin{array}{l} 119,\ 458,\ 1460,\ \ldots.\ \cdot 25\ \ldots\ 0\cdot 25 \\ 158,\ 859,\ 1155,\ \ldots.\ \cdot 70\ \ldots\ 72\cdot 70 \end{array}\right. \ldots.\ 72\cdot 45$$

This is computed as follows:

$$\frac{458 - 119}{1460 - 119} = \frac{339}{1341} = \cdot 25 +$$

and similarly for the other fraction of a vibration.

If, under the microscope, there seemed to be any uncertainty as to the exact position of the tangent point (on *c d*) or of the wave crests, the observation was either rejected altogether or was weighted according to judgment. But, as shown below, an observation weighted low has not in general the greatest variation from the accepted mean of the series.

The values obtained on a series of twelve observations were 72·53, 72·59, 72·57, 72·53, 72·35, 72·44, 72·41, 72·57, 72·48, 72·31, 72·56, 72·50. The first and ninth were given a weight of 1 on account of uncertainties in their determination, and all the others a weight of 2, but the ninth very nearly equals the finally accepted mean, and the first has not as much variation as many others. The mean thus computed is 72·487 vibrations. The rating of the fork was determined by means of a series of observations with a standard clock to be 100·471 vibrations per mean second. The mean time, therefore, equals ·72147 second. The probable error for the mean of this set was found to be ·00018 second.

After experimenting with forks with higher rates, it was decided that a fork vibrating 100 times per second was the best. With 1,000 vibrations per second, the vibrations have but little amplitude, and it would be difficult to do more than count the whole number of vibrations with certainty. With the fork used, it is comparatively easy to produce and maintain an amplitude of one-eighth inch to one-quarter inch for the whole observation. Then, when the cylinder is turned about one-quarter inch for each vibration, a curve is produced on which the crests are very definite. In fact, the greatest uncertainty in the determination is generally in locating the exact position of the point of curvature on the line traced by the recording armature, and since this point is better defined when the cylinder is revolving more slowly, it becomes all the more necessary that the vibrations per

second should not be so increased that the speed of the cylinder must be increased in order to render the vibrations distinguishable.

Of course, the accuracy of this method depends on the uniformity of the rotation of the cylinder during the vibration considered, but the probable change in the velocity of rotation of the heavy cylinder during ·01 second is evidently so small that its effect on these computations would be inappreciable.

ITHACA, N. Y., February 19, 1892.

PHYSICAL EXERCISE IN HEALTH AND AS A REMEDY.

By J. Madison Taylor, M.D.

[*A lecture delivered before the Franklin Institute, December 7, 1891.*]

The human body is usually assumed to be fairly symmetrical as to its parts and healthy in its organic workings. This is more nearly true now perhaps than a century or two gone by, and in certain communities, but is far from true of other localities and earlier times. There are conspicuous instances in history of peoples among whom for long periods a very high standard of physical perfection prevailed. It may be remarked that along with this was observed also a large measure of intellectual vigor. If among the young of our own families and friends, search be made to-day, there will be disclosed a pitiably large number of defective organizations, needing judicious care to develop into normal men and women. If this assertion should be challenged, little demonstration would be needed to make the matter clear. Further, invaluable records are now growing which leave no reasonable ground for doubt, as I shall show anon. (*Sargent's Normal Man*, etc.)

These instances of "half-built boys," as Blaikie calls them, will be obvious to a critical observer in any gathering of youth.

I claim it is the plain duty of all medical men and teachers to recognize such cases and provide remedies within their jurisdiction and powers. The child being father of the man, and he again of other men so long as the race survives, it should be the blessed prerogative of the physician to stamp out insidious seeds of disease, to enhance the vital forces of the men to be, by aiding to equip the child with all potentialities his present heritage and domestic plane can be made to furnish. We can and should help the growing bread-winner to sharpen his capacities and broaden his powers, not only in one but remote generations.

Medical art and science is but the common-sense presentment of vital laws applied to keep the body whole. When wrecks have occurred we must work night and day to get these again afloat, patch up the leaks if possible, and restore to such normal plane as may be. Our best prerogative, however, is to act as pilot, and, armed with authority, warn vessels off shoals. More than this, we strive to act in prophetic capacity, foretelling the weather and dangers that lie far hence; how human ships may be more wisely constructed, more speedily and economically run, and, in short, exert a vigilance that may tend to save and expedite the mortal crafts that sail on treacherous seas.

First, then, let us give more and increasing attention to conserving, and increasing to the uttermost the forces of our boys and girls; next in importance, and of less promise in possibilities point out to adult folk how they may maintain and add to their working powers. Lastly, we will consider the remedial power of simple exercises in re-establishing the lowered health.

The first instinctive movements of a healthy child are rhythmical and graceful, though of most limited scope. If not hampered, as too often happens, by inappropriate clothing, these will rapidly improve in power and coördinative range till the full measure of his inherent capabilities be reached. Given continued health, ample space and energy enough in any reasonable climate, and children will develop into wholesome men, competent to do their duty in whatsoever range that may lie. Let these fair conditions

be absent in whatever degree and infinite skill and pains are needed to save and shape the inherent power.

Practically, it is always needful to husband and wisely conserve growing forces.

Health.—Health has been briefly defined as a "balance betwixt the various parts of the organism in power as well as in function."

A hasty review of these processes may be useful to make clear the deductions further on.

Life in its simplest acceptation involves the idea of constant change. We do not consider a being as alive which is not undergoing some continual alteration, however slow and obscure. This alteration may be evidenced by the growth and extension of the organic structure, or by molecular changes in its substance which do not produce any ostensible increase; or it may be most obviously manifested in movements such as cannot be attributed to any physical cause. The life of any complex organism, such as that of a man, is, in fact, the aggregate of vital activities of all its component parts. In every living structure of complex nature, whilst we witness a great variety of actions resulting from the exercise of the different powers of its several component parts, we at the same time perceive that there is a certain harmony or coördination among them all, whereby they are made to concur in the maintenance of the life of the organism as a whole. If we take a general survey of these with reference to their mutual relationships, we shall perceive that they may be associated into groups, each consisting of a set of actions which, though differing among themselves, concur in effecting some positive and determinate purpose. These groups are termed functions.

The exercise of the animal function is essentially destructive of these instruments; every operation of the nervous and muscular systems involves as a necessary condition, a disintegration of a certain part of their tissues; so that the duration of the existence of those tissues varies inversely to the use that is made of them, being less as their functional activity is greater.

A compensating operation of the constructive function is

therefore required in order to repair the loss of substance thus occasioned; from which it happens that the demand for nutrition, and therefore the necessity for food, is in great degree regulated by the functional activity of the nerve-muscular apparatus. We are not, however, to measure the activity of the nervous system, like that of the muscular, only by that of movement to which it gives origin. For there is equal evidence that the demand for blood in the brain, the amount of nutrition it receives and the degree of disintegration it undergoes, are proportional, likewise, to the energy of purely psychical operations, so that the vigorous exercise of the intellectual powers, or a long-continued state of agitation of the feelings, produces as great "waste" of nervous matter as is occasioned by active bodily exercise.

The functions, therefore, of the animal body are so completely bound up together that none can be suspended without cessation of the rest. The properties of all the tissues and organs are dependent upon their regular nutrition by a due supply of perfectly elaborated blood. This cannot be effected unless the functions of circulation, respiration and excretion be performed with regularity, the first by necessity to distribute the supply of nutritious fluid, the second being requisite for its oxygenation, and also needed in conjunction with the third, to free it from impurities which it contracts during its circuit. The respiration cannot be maintained without the integrity of a certain part of the nervo-muscular apparatus; and the due action of this again, is dependent not only upon its regular nutrition, but also upon its supply of oxygen. The materials necessary for the replacement of those which are continually being separated from the blood can only be derived through the absorption of ingested aliment, and this cannot be accomplished without the preliminary process of digestion. In order that an organized fabric may be maintained, it is obviously needful that there should be a ceaseless supply of needed particles; that these, when certain elements have been used up, be replaced by others. Again, if the processes of waste and decay be not compensated by renewals, there results starvation or exhaustion.

During the whole period of growth there is ceaseless remodelling of the whole structure, the life of each part being brief to enable its renewal on a different scale. Children, therefore, require more food in proportion to their bulk. Old persons, in whom the ebb and flow of vital activities are sluggish, where waste and repair are retarded, need less. The production of heat needs extra food to maintain the temperature of the body in varying atmospheres.

During great activities and in cold atmospheres much food is demanded, the more readily combustible with least waste, the better.

Digestion prepares the nutritive materials to be thus conveyed to the tissues. These undergo important changes in their progress toward the centre of the system till they become pure blood. This is the true vital fluid, which reconstructs the tissues, and gathering up the waste of the circulation, submits itself to the bath of oxygen in the lungs, where it is again made fit to start on its life-giving course.

The propulsion of the flood through the large vessels which subsequently divide into capillaries, is due to the contraction of a hollow muscular organ—the heart. These, like the pulsating movements of the alimentary canal, are largely independent of the agency of the nervous system. The rate and force of these vascular movements are greatly influenced by states of nervous energy, thereby calling into play the contractility of the arterial walls, exert a powerful effect upon their calibre, and consequently on their distribution of blood to particular parts and organs.

The steady disintegration which incessantly occurs in living tissues, renders it imperative that efficient means be provided for conveying away waste. This is almost as important as that new material should be supplied, and is especially to be emphasized in connection with the subject of muscular exercises. The venous system takes away a large part of the products of incipient decomposition, and transfers these to the organs of excretion, by which they may be seperated from and cast out of the body. The first product of the decay of all organized structures is carbonic

acid; and this is the one which is most constantly and rapidly accumulating in the system, and the retention of which in the body is the most injurious.

Accordingly we find a most important set of organs, the respiratory apparatus, adapted to this end. Through this the whole current of the venous blood passes before it is again sent about the system. Here, spread out upon the meshes of the lungs, it is exposed to the atmospheric air whereby the carbon dioxide is removed and replaced by oxygen, in accordance with the physical law of the diffusion of gases. The introduction of oxygen into the blood is peculiarly essential for the maintenance of those vivifying powers by which the nervous and muscular systems are kept in a state of normal balance. The demand for oxygen and excretion of carbonic acid vary according to the amount of nervo-muscular action put forth. The continual formation of carbonic acid in this and other interstitial changes, has a most important purpose in the vital economy—that of keeping its temperature at a fixed standard.

The function of the greatest excreting organ of the body—the liver—is like that of the lungs, twofold; it separates a large quantity of superfluous hydrocarbon from the blood which this acquires while circulating through the tissues, and it combines this with other elements into a secretion which is of the greatest importance in the digestive process.

But further, all animal substances have a tendency during their decomposition to throw off nitrogen as well as carbon, and this nitrogen in combination with other elements forms those peculiar azotized compounds which it is the special duty of the kidneys to eliminate from the circulating fluid. The most characteristic in man is urea. This contains a larger proportion of nitrogen than is found in any other organic compound.

The action of the kidneys, which also serve as emunctories for various soluble matters, especially saline, is equally essential to the other vital functions with that of the lungs and liver. The regulation of the amount of fluid in the vessels is provided by a kind of safety-valve structure in

the kidneys, which allows the escape of watery fluids from the capillary vessels into the urinary canals by transudation. This is quite distinct from the secretion of that solid matter which it is the special office of the kidney to separate from the blood. Hence, if the excretion of the fluid from the skin be checked by cold, the increased pressure in the vessels causes greater escape of water through the kidneys.

All digestion, as Fothergill picturesquely describes it, "is a process of solution by hydration." Hence, if the ingested water be not sufficient, not only does digestion suffer, but all the secretory organs fail. One of the first and most conspicuous advantages of bodily exertions is, to demand by thirst an ample measure of this invaluable solvent.

Effects of Exercise; Phenomena of Muscular Action.—During the process of muscular contraction there is put forth the power of converting latent energy into muscular force. This property is inherent in the muscle, and is controlled by nervous discharges. Little is known of this mysterious influence of nervous energy other than that it travels as a wave of molecular disturbance along the nerves to thin, terminal expansions in the muscular fibres. On its arrival there it is converted into muscle impulse. Along with this certain electrical phenomena are manifested. These contractile movements are accompanied by molecular vibrations, which give rise to a distinct humming sound. In damaged muscle, as in palsies, the normal pitch of this musical note is lowered, the number of vibrations being lessened. The normal temperature falls slightly at the beginning of the contraction, but often rises above that in quiescent states, and continues to increase for a time after the cessation of activity. The flow of blood is increased during voluntary contraction as the capillary vessels in muscle run between the elementary fibres. The amount of blood supply, and in consequence the capacity for prolonged. work, must vary for the same bulk of muscle in proportion to the smallness of the fibres. In women these fibres are of smaller size than in men, and Haughton claims to have found by direct experiment that "the muscles of women

are capable of longer-continued work than those of men, though inferior to them in force exerted for a short time." Important chemical changes take place in muscle during contraction, but our knowledge of these is not yet clear. The muscle substance becomes distinctly acid then, whereas in repose it is neutral, and the splitting up of organic molecules becomes active, throwing off carbon dioxide and urea. Respiration is increased most markedly during exercises in which the whole body partakes. A careful estimate made by Dr. Edward Smith shows that the quantity of air inspired varied from one, in a sitting posture, thence through a series of acts, such as standing, walking, slowly riding, and finally walking and riding rapidly, carrying weights, etc., until at last while running six miles an hour, the unit is multiplied nearly seven times. The elimination of carbonic acid from the lungs, he estimated carefully with similar results. During the most moderate exercise, the increase in force and frequency of the heart beat is very great and sudden. The vessels dilate, the blood stream is rushed swiftly through the body, and particularly to the muscles where required.

General Effects of Exercise.—To get a right estimate of the effects of muscular work on an adult person of normal nutrition, it would probably be more instructive to begin by considering the results of insufficient exercise. Here, the nutritive processes continuing in healthful activity, there comes a state of over-nutrition, or undue piling up of assimilated matter. This process can continue without disturbance for a very considerable length of time, and until a greatly increased and exuberant state of nutrition results. Thus persons who have a tendency to become fat accumulate vast masses of fat on their surfaces where it is safe enough. Unfortunately, this may go on until the deeper structures are infiltrated, which constitutes a diseased process. A certain amount of this reserve fat is of use, upon which the vital forces may draw at need. Again, this has its value for those who are exposed to low degrees of cold; and, further, if one should fall into a fever, a fair amount of fat enables him to run a long time without the need for

other than the smallest amounts of new food. There are many discomforts, of course, which are produced by this large addition to one's weight which makes it worth the while of those so discommoded to seek for it a remedy. Again, in those whose nutrition is not so good, there comes about a lowered state of vital forces due to an insufficient admission of oxygen into their tissues. All the organic processes become impaired if the normal amount of oxygen be not supplied. A torpor grows not only upon the muscular movements, but upon the *will*. The heart, it is well to point out here, is one of the first organs to suffer from insufficient use of the entire body. The mechanism of this is interesting, and, since the fact is so important, it is worthy of description. The mass of blood, as has been described, is pumped by the heart into the great vessels which distribute it. Thus, the heart receives the blood and instantly pumps it out again. How, then, can the heart itself be nourished? In a state of normal tension of these larger blood vessels, the heart throws just enough blood at each beat to fill them to a point of normal fulness. This brings into play the elasticity of the vessel walls, which is very great. The supply of blood which goes to the heart comes to it by two small vessels whose opening is just beyond the limits of the heart muscle, and are called the coronary arteries. If the heart by any reason becomes over-weak, this impulse of the blood produces an insufficient reaction to press a needful supply into these little nutrient vessels, and hence they languish. Many disturbed states of the heart bring about this result. If the blood be not sufficiently oxygenated, an effect is wrought by this upon the heart muscle itself, and acting with it, the larger vessels. Thus is the vascular tension lowered and a progressive enfeeblement of the heart pump brought steadily about. Hence, the balance of the circulation is lowered in its most essential point. As the oxygen is supplied more abundantly and active movements effect this, the whole round of circulatory activities is invigorated. The heart not only itself becomes better nourished; it sends out at each beat a fuller measure of blood. This moves with a more per-

fect rhythm throughout the lesser vessels into and out of the tissues, and is finally returned to the right heart and thence to the lungs, where the respiratory need is also enhanced and re-oxygenation is made more perfect. Thus it will be easy to see how all the organs are enabled to do their duty better. But to organs long unaccustomed to this stimulus of abundant oxygen, the slightest muscular exertion causes palpitation and breathlessness. The lungs, unaccustomed to large demands upon them, can only bring into active use a limited proportion of their air cells, many of which have become collapsed and flabby, and are able only to expose a limited part of their area. Prolonged inactivity, too, enfeebles the eliminative power of the muscles. The sense of fatigue is greater, the distress of breathlessness likewise excessive, and all things combine to indispose one to effort. In short, the state of tissues in a man long unaccustomed to right activities, is simply that of filthiness, by retained poisons. All the tissues of the body, notably the most important one—the blood—all the larger glands whose function is chiefly that of excretion, are not only in a state of lowered activity, but contain longer than they should these poisonous by-products of digestion. Hence, these are enabled to exert their virulence upon the nerve centres, and all are measurably limited. To be sure, the marvellous adjustive power of the human organism enables one who becomes thoroughly accustomed to inactivities, to enjoy a very fair amount of health and to accomplish ample work. This is done, however, usually at considerable cost of discomforts, or by means of artificial aids of some kind.

Shocks to the heart mechanism are able to work damage. Rupture of its tendinous chords and valves have been caused by sudden and excessive strains. This is usually the result of inordinate efforts under the influence of fear or emotion. Also in one quite unused to muscular strains this may happen. Small evidence is adduced to show that this organ is ever damaged by reasonable strains in one even moderately well trained. It is rare enough among

laborers, iron workers, glass blowers, and such. Few athletic sports can be accredited with power to do so. The tug of war offers some danger and heavy weight lifting, dumbbell pulling, etc. Instances even here are rare. I wish to learn of all such, and will fairly sift and record them in future papers.

Let us look, then, upon the more attractive side of the picture, namely, the processes which are observed during exercise. Dujardin-Beaumetz says: "Under the influence of gymnastic exercises the activity of the cellular functions increases and becomes more regular, the intra-cellular combustions become more active, the leucomaines, those toxic materials which the organic cell is constantly manufacturing, are more actively eliminated, and the general effect is that the fats are burned up and the cellular functions regulated. There is established an equilibrium between the cells of the spinal cord and those of the brain; in a word, general nutrition becomes more active."

Indeed, all the cells of the body receive an increased stimulus from nerves and blood. Exercise, as pointed out, profoundly modifies the structure of the blood. During the actual process of muscular work that of dissimilation is made more active owing to the greater vigor of cell combustions, the muscle becomes actually hotter and destructible parts of it are burned up. This over-production of heat which accompanies work, and the vigorous combustion of the hydrocarbons of the body and their elimination from the system as waste products, cause loss of weight. This increase of combustion causes greatly increased respiration. The oxygen entering the lungs takes the place of that which is used in the combustion, and the final result is not actual loss, but at times a positive gain by reason of this gas. The recognizable loss of weight which occurs immediately after prolonged hard work is from elimination of watery elements through skin and lungs. Active exercise, then, introduces more oxygen into the system than is needed for the combustion. The difference between the arterial and venous blood of a man in perfect physical condition is in much more vigorous contrast than in the same

man during a period of inactivity. What the precise difference in weight of blood would be, it is impossible to know. The improved quality of the arterial blood, aside from the fact that it can place nutritive materials more valuably to the remoter tissues, does much more than this. The more nearly pure it be, and this property is almost altogether due to the completeness of its own oxygenation, so much more are the different kinds of cells in remoter parts of the body revivified.

So, also, are the products of cellular combustion more swiftly and efficiently taken up and carried back to the furnace of the lungs. There then comes as one of the most notable evidences of this improved state, a subjective sense of invigoration, which in itself is delightful. Muscular work, then, as a regulator of nutrition, is equally useful to those who do not assimilate enough and those who do not dissimilate sufficiently. Hence, very nearly the most clearly defined instinct, after that of searching for food, is to make movements of the body. If hunger for food or drink is the first instinctive appetite, assuredly the next is for those movements which enable us to keep our bodies still active. The appetite for food and drink can never be quite killed; the appetite for exercise dies hard, but if persistently thrust into abeyance it may almost go, especially in late age. Even among old people, however, in whom the taste for narcotics becomes highly developed, a desire for a daily walk is almost universally seen. In nearly all animals, however, of high or low degree, this appetite for movement is as recognizable as that for food and drink. It has never received a name, though really it deserves one. It might, perhaps, be called "air hunger."

When this vivifying oxygen is insufficiently supplied to the blood, its contact with the cells fails to give to them that needful stimulation which makes their working smooth and competent, and brings out their latent energies. Hence the appetite fails through insufficient stimulation of the digestive organs; the stomach and intestines lose their tone; the bowels become inactive, especially in places. These eddies in the bowel act as centres from which leuco-

maines and other putrefactive matters are more readily absorbed, instead of digested aliment, into the blood. Thence arise feelings of weakness; the muscles lose their irritability and respond less readily to the mandates of the will. In short, all the functions languish, and the human machine weakens. Again, the insufficient combustion of reserve materials remaining in the system, leads to disturbed states of health and actual disease. The most familiar of these is gout, as to which all of the human races and certain animals have some practical familiarity. But there are many similar conditions distressing enough, too, which arise from this cause. Indeed, among many animals this very disease is presented, and it is scarcely necessary to point to the wretched state of the over-fed, over-cared for inhabitants of zoölogical gardens, to see a picture ready at hand of the woes of forced inactivity.

The Phenomena of Over-work.—A muscle which has been induced to contract repeatedly at last reaches a condition which we call fatigue, and then under the stimulus alone of the will it cannot be made to further act. At first this is only relative. By passing an electric current through this muscle thus fatigued, it can be made to contract a certain number of times further, but finally there comes a period when the fatigue is absolute and the muscle has lost its power of contractility from any stimuli. The human muscle, however, never reaches this extreme point of exhaustion. The central consciousness is early made aware of this phenomenon by the sensation of pain. This pain finally becomes unbearable, and hence the muscular acts must be made to cease. This pain in muscle subject to over-contraction is the result of repeated shocks and disturbances occasioned in the mass itself and neighboring tissues. The muscle is traversed by a number of sensory nerve filaments. These little tendrils are rubbed and pinched by movements of the muscular fibres which swell and harden during the energetic contraction of work. These muscular fibres are themselves pulled about and the tendons and flat surfaces of insertion, the synovial membranes, undergo repeated friction. A positive injury, then,

is the local result of excessive muscular work, very similar to that which is produced from external causes such as bruises. Also in the body of the muscle itself modification of metabolism occur owing to the combustions which take place during contractions. Each muscle during contraction becomes heated, and this increase of temperature is due to the chemical combinations already described. These toxical agents affect the muscle itself directly and inhibit further contraction. If these are not formed in too great excess, they are readily carried away by the blood. If, however, the work is continued too long they accumulate in the muscle. There is, therefore, a vital process and a chemical one involved in local fatigue, each of which must be considered in judging of the result. Inherent muscular power may be never so great but that unless the domination of the will be sufficient to drive it, small results can come from its activity. Thus we see the instances of powerful animals whose mechanical powers are almost unimpaired, but who yet have had their will so dominated by that of another, or by the feeling of fear, that their tremendous machinery is made of no account.

Per contra, it is perfectly possible to apply a stimulus to the will of a dominated animal, or man, by which this machinery can be driven on and on to the point of profound exhaustion. This is often seen in horses and beasts of burden. Other factors come in here which we will describe later. It is rarely seen in man, however, although in some of the modern brutal exhibitions, such as long-walking matches, and the like, greed and vanity drive men to the limits of endurance and over into destructive effects.

The sense of fatigue which comes upon us as a subjective warning, enables our economy to learn in most instances quite clearly when we are overdoing or overdriving our powers. If we do err in pushing them yet further, this verges upon damage. During the expenditure of muscular force which is the result of automatic action, fatigue is much more slowly produced; hence, strictly speaking, a muscle with precisely the same inherent power can be made to do more work than if the tissue was strongly elicited.

Also automatic actions are less wastefully performed. There is a non-economical expenditure of force where an element of worry and mental strain comes in to complicate the process. A large series of muscles, however, is called involuntary. The structure of these, indeed, is somewhat different from the voluntary muscles. The movements of organic life, such as the heart beat and the respiratory movements, etc., are instances of this automatism. These organs never become fatigued; they may become exhausted, however. Under all reasonable and many unreasonable circumstances this wonderful pump, the heart, puts forth a force at each contraction of raising a weight of forty kilogrammes, one centimetre high, and does this sixty times to the minute, and continues this process from the cradle to the grave.

So, also, of the respiration. This complicated series of acts goes on without interruption throughout the entirety of life. Here, however, there is the double power of automatic action and direct volition, since we can increase the force or frequency of our breathing at will. It is extremely interesting to consider how widely individuals vary in their capacity to endure fatigue.

As I mentioned elsewhere, the quality of muscle differs considerably, but this is a little matter compared with the varying capacity of enduring the nervous strain in these nervo-muscular acts. Certain highly irritable natures are often readily exhausted, but if the stimulus to their minds be sufficient, these can be induced to make an output of energy which would far outstrip in results a cooler or more phlegmatic person. Also the results to them subjectively might be far more serious than to the phlegmatic person driven to do very nearly the same amount of work. In prescribing the amount and kind of bodily exercises, it is almost more important to weigh this question of temperament than any other single consideration. It is especially needful in persons of easily disturbed nervous balance to suggest the use of exercises which may not need sustained attention; certainly this at first, also, that these should be, as much as possible, automatic, until their powers warrant

larger excursions. One of the first sensations of discomfort which comes from unaccustomed exercises is loss of breath. To be sure, the breath is not lost, but many times the impression is given to us that it is, indeed, all but gone.

I remember very well that wise mentor Blaikie giving us upon the eve of a boat race, which was to be three miles long, this excellent counsel: "Now, boys," said he, "this is a three-mile race. Work steadily from the first. When you reach the second mile you will feel that your end has almost come. At about two miles and a half you will be sure that your breath has gone; but don't believe it. Always bear in mind the fact that every other man in your boat, and every other man in every other boat, feels precisely as you do. The man who works hardest in spite of all this, is the man who wins the race." Now, happily, a limit is put in all racing, both of man or beast, within the average capacity, a definite distance being fixed. Therefore, it is perfectly feasible to work up to the verge of your own conscious powers. We are subject to few more distressing feelings, however, than to the sense of breathlessness. This has been best described and, indeed, I am not so sure but also first described, by Lagrange: "Breathlessness is a feeling of distress which is produced during violent exercise or intense muscular work, and is characterized by an exaggeration of the respiratory need and by profound disturbance to the function of the respiratory organs. This state is merely a peculiar form of dyspnœa, and presents the general phenomena due to deficient aëration of the blood."

In certain muscular actions the distress comes in the shape of breathlessness, and in others, muscle contraction pain. For instance, in climbing up a ladder, hand over hand, a man must stop from sheer muscular incapacity long before he is out of breath. This is largely because the muscle is not properly trained to the act from long usage. In the act of running, however, a man must stop from sheer breathlessness long before his muscles are even tired. Here the explanation, too, is partly on the ground that the use of

the legs is almost incessant and they become inured to a vast amount of work.

Trainers say a horse trots with his legs and gallops with his lungs. It is necessary to distinguish between speed and gait. The act of galloping is one of the most natural movements to a horse. To do this slowly requires a peculiarly beautiful poise and grace. Horsemen will rate a horse's value under the saddle largely upon his capacity to gallop slowly; yet this is not necessarily so comfortable a gait to the animal in the long run as trotting. The trot is a much more artificial gait, and yet when once learned (for, indeed, it is largely the result of teaching), the pace can be maintained longer and with less distress.

Again, to quote from Lagrange: "In every muscular exercise the intensity of breathlessness is in direct ratio to the quantity of force expended in a given time. If certain exercises cause breathlessness more than others, this result is not due to special movements or particular attitudes which they occasion. The quick advent of breathlessness is not due to the contraction of certain muscles, to the displacement of certain bony levers, or to the mechanical disturbance which certain organs undergo during exercise: it is due to the rapid and excessive expenditure of force which the exercise necessitates." This respiratory distress is in a measure a defence against an imminent danger. When the blood becomes surcharged with carbonic acid, death may be caused in a few moments. This is the product of dissimilation resulting from vital combustion, and should be constantly eliminated by the lungs. It is possible to endure without hurt a definite amount of carbonic acid; poisoning beyond this point is dangerous. The presence of this poison in the blood causes us instinctively to draw in more and more air. The elimination of this product varies widely under different circumstances. The experiments of Regnault show that during the period of hibernation the carbonic acid output of an animal is but one-thirtieth when awake. Immediately on being awakened the need for oxygenation becomes imperative. During overactive movements in the open air there can be no dearth of

oxygen. Dyspnœa from exercise can only be the result, then, of the over-loading of the blood by this form of poison, of overcrowding the eliminative powers.

Other factors come in to produce this distressing phenomenon, among which may be mentioned the emotions. Under the influence of fear, breathing is noticeably disturbed. This is more readily seen among human beings, but also observed among hunted wild animals who are oftentimes readily captured if completely terrified.

[*To be continued.*]

SOME ADDITIONAL NOTES ON THE GRAPHIC REPRESENTATION OF MAGNETIC FIELDS.

BY PROF. EDWIN J. HOUSTON.

[*Addendum to a paper read before the Electrical Section of the Franklin Institute, June 28, 1892.*]

In a paper read at the last meeting of the Section, entitled "A Graphic Representation of the Magnetic Field," I described a process for readily fixing and reproducing the peculiarities of different magnetic fields, which consists essentially in forming the fields on wax-covered plates, subsequently fixing the same by gently warming the wax, and employing the plate so prepared as a positive from which photographic prints can be readily obtained.

I also briefly described in the same paper a different process for the ready reproduction of such fields, in which the collections of filings are formed in the dark photographic room, directly on the sensitized surface of a plate, which is afterwards exposed for a few seconds to actinic light and subsequently developed, and promised a further description of this method at this meeting.

It will readily be seen that this process differs from the other, in that it produces photographic negatives, in place of the positives formed by the former process.

Since the last meeting of the Section, I have experimented some little on the new process, and have obtained very satisfactory results.

For the convenience of those who have neither read the former paper, nor attended the meeting of the Section at which it was read, I will describe the process in full, together with the details which are necessary in order to ensure the best results.

All actinic light being excluded from the dark room, and the red light being turned down as far as will permit the plate to be seen, when the eyes have become accustomed to the dim light, a sensitized gelatine plate is placed with its sensitized surface upwards, on, or a short distance above, the magnet whose field is to be obtained. Iron filings or bits of wire are then carefully dusted over the sensitized surface, and obtained thereon, in characteristic groupings, by gently tapping the plate with a pencil or similar object in the usual manner.

The plate is then exposed to the light of a gas jet for a length of time that will of course depend on the nature of the plate, its sensitometer number, and the character of the effect it is desired to obtain.

When very rapid plates are used, the shortest time during which a gas burner can be turned on and off is sufficient. I have, however, obtained the best results from the light of an ordinary friction match held above the plate and at a distance from it of about twelve feet. The match is lighted and immediately blown out. Even this short exposure appears to be greater than is required. With fairly slow plates I have found that an exposure of about three seconds, with a two-candle gas jet, at a distance of about four feet from the plate, gives excellent results.

The plate is then turned on edge so as to allow the filings to fall off its surface, and any dust that remains is carefully removed by a camel's-hair brush, and the plate is developed in the ordinary manner.

Since it is desired to obtain sharp contrasts of black and white, the best results are obtained by the use of bromides in the developer for the purpose of retarding the rapidity of development. After developing, the plate is treated for a few moments to an alum bath, and is then fixed in the hypo bath as usual.

Should the depth of the negative thus obtained be insufficient, the plate may be subjected to the action of a suitable intensifier. I have found a silver intensifier to give good results.

The specimens which I exhibit to-night were obtained either from Carbutt's or from Seed's gelatine plates.

In some of these experiments, Carbutt's plates, sensitometer No. 16, were exposed for about three seconds to the light of an ordinary gas burner, turned down to about two candles, and situated about five feet from the plate. From some experiments in this direction I am inclined to believe that the time of exposure under these circumstances can advantageously be decreased.

I employed for these plates the following developer:

NO. 1.

Water,	16	ounces.
Sulphite of soda,	307	grains.
Para-amido-phenol,	$76\frac{3}{10}$	"

NO. 2.

Water,	16	ounces.
Sulphite of soda,	307	grains.
Caustic soda,	230	"

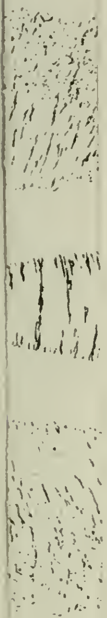
Equal parts of Nos. 1 and 2 are mixed for use. For time exposure the above mixture is diluted with from two to four parts of water.

Any good developer, however, will answer.

I have also used Seed's plates, sensitometer No. 23. With these plates the momentary turning on and off of the gas jet gives a sufficiently long exposure.

I have also obtained very good results with Seed's plates sensitometer No. 26-x. With these plates my friend, F. Gutekunst, of Philadelphia, has prepared some excellent fields.

In order to protect the plates from the light of the gas jet while lighting it, so as to avoid too long an exposure, the expedient was adopted of covering the plate with a developing dish until the light was turned on. It was then exposed while the dish was being rapidly removed from the plate



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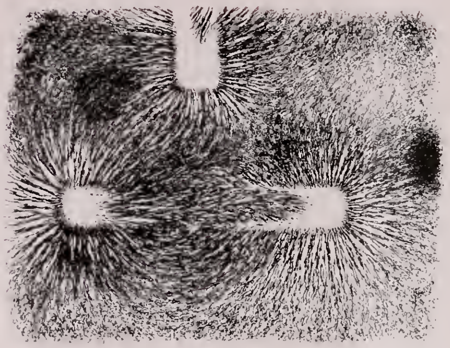

Fig. 7.—Field of Straight Bar Magnets with one Magnet near Neutral Point of the Other.

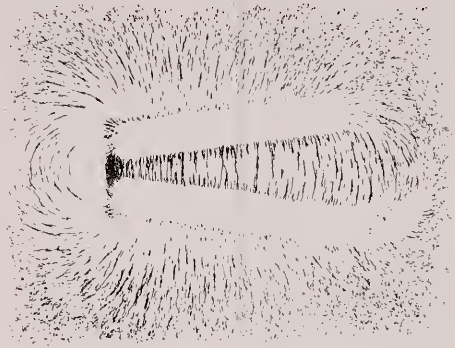

Fig. 8.—Filings Field of Simple Horseshoe Magnet.

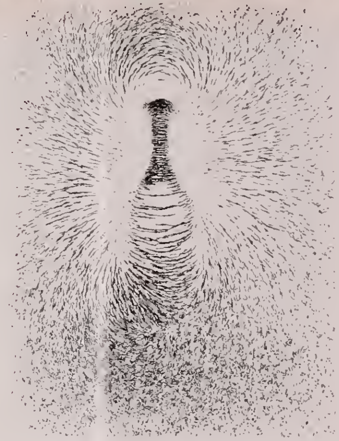

Fig. 9.—Field of Horseshoe Magnet with Longer Axis Horizontal to Plate.

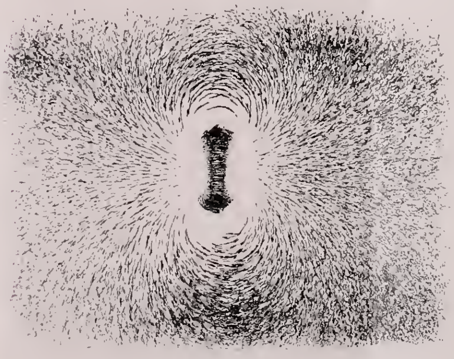

Fig. 10.—Field of Horseshoe Magnet with Longer Axis Vertical to Plate.

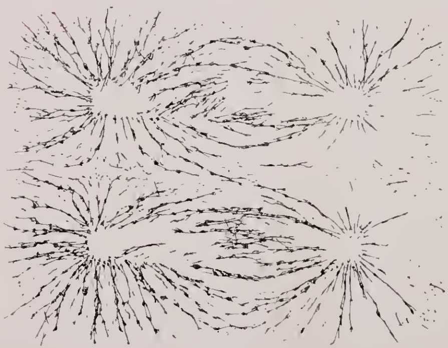

Fig. 11.—Compound Field of Parallel Bar Magnets with Similar Poles Approached.

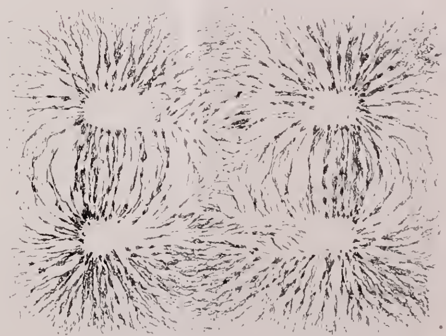

Fig. 12.—Compound Field of Parallel Bar Magnets with Dissimilar Poles Approached.

the gas being turned off when the dish was about one and one-half feet distant from the plate.

While myself out of the city and, therefore, away from my laboratory, my friend, Mr. F. R. Lefferts, of the Celluloid Company, of New York, kindly placed a photographic dark room at his cottage, at Belmar, N. J., at my disposal during these experiments. I am also indebted to him for valuable aid in preparing the photographic plates.

Fig. 1 shows the wire field of a straight bar magnet of steel. This corresponds to the bar magnet, the field of which was shown in the first paper on *Fig. 10*. This, like the other wire fields, was obtained by the use of short lengths of soft iron wire instead of iron filings.

Fig. 2 shows the filings field of a simple horseshoe magnet. The anomalous poles in this magnet show very peculiar groupings in the neighborhood of what was originally the neutral point of the magnet. These poles were probably caused by some unauthorized juvenile experiments I had not counted on being made.

Fig. 3 shows the field of two parallel straight bar magnets with their similar poles approached. This figure corresponds to *Fig. 5* of the first paper.

Fig. 4 shows the field of two parallel straight bar magnets with their dissimilar poles approached. This figure corresponds with *Fig. 6* of the first paper. The conditions for the exposure of this field were more favorable than for most of the others, and the print shows what can be hoped for when the proper conditions necessary to ensure the best results are exactly understood.

Mr. Lefferts has kindly prepared for me an excellent transparency of this field, which I now show you.

Fig. 5 shows the field produced by two straight bar magnets placed with their axes at right angles to each other, and with their similar poles approached. The characteristic parallel streamings, produced by the repulsion of similar lines of magnetized particles, are clearly shown.

Fig. 6 shows the field produced by the straight bar magnets with their axes at right angles to each other and with their dissimilar poles approached.

Fig. 7 shows the field of the two straight bar magnets placed with their axes at right angles to each other, and the pole of one near, but not in contact with, the neutral point of the other. This corresponds to *Fig. 4* of the first paper.

Fig. 8 shows the filings field of a compound permanent horseshoe magnet. This figure corresponds with *Fig. 7* of the first paper.

Fig. 9 shows a curious field of the same permanent horseshoe magnet shown in the former paper in *Fig. 9*. In this figure, however, the magnet is placed with its axis in a horizontal position, while in the figure of the first paper it was placed in a vertical position. I have reproduced *Fig. 9* of former paper in *Fig. 10* for ready comparison. The leakage, in planes at right angles, is well shown The magnetic leakage in this case gives the curious appearance of a "beatified bottle."

I also show you a number of aristotypes prepared for me by Mr. Lefferts.

I have formed some curious compound fields with filings and wire mixed. *Figs. 11* and *12* show such fields corresponding to *Figs. 3* and *4*, as shown above.

AMERICAN ASSOCIATION OF STATE WEATHER SERVICES.

[*Summary of proceedings of the first meeting, held at Rochester, N. Y.*]

A convention of representatives of State Weather Services was held in Rochester, N. Y., on August 15 and 16, 1892, in conjunction with the forty-third meeting of the American Association for the Advancement of Science. The convention was called to order by Prof. Mark W. Harrington, Chief of the Weather Bureau, who made an address of welcome to the representatives present. He suggested certain important subjects for discussion, and appointed committees on permanent organization, programme, etc.

A permanent organization was effected, and the following officers were elected: President, Major H. H. C. Dun-

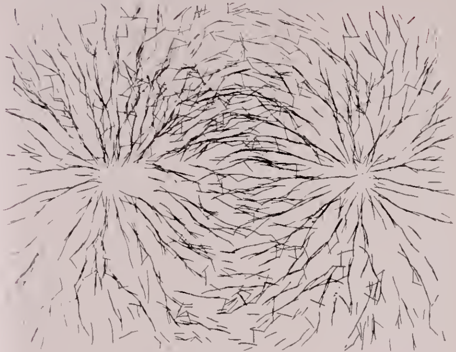

FIG. 1.—Wire Field of Bar Magnet.

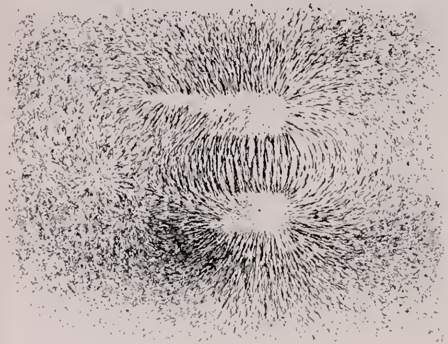

FIG. 2—Field of Simple Horseshoe Magnet.

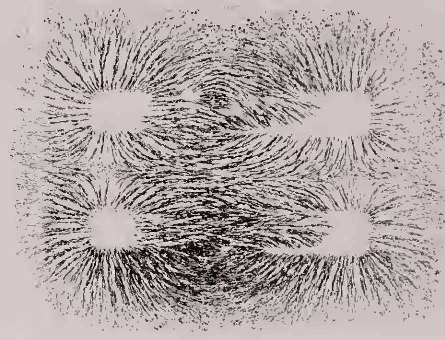

FIG. 3.—Field of Parallel Bar Magnets with Similar Poles Approached.

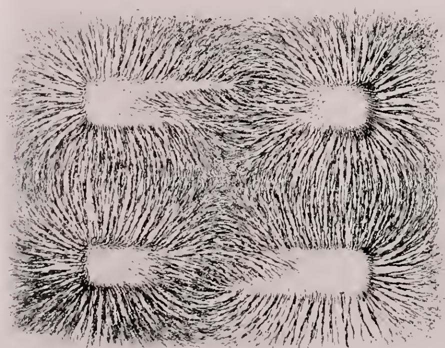

FIG. 4.—Field of Parallel Bar Magnets with Dissimilar Poles Approached.

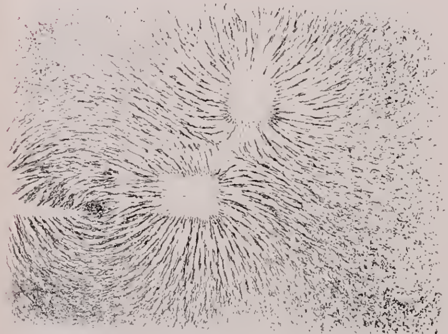

FIG 5.—Field of Straight Bar Magnets with Axes at Right Angles and Similar Poles Approached.

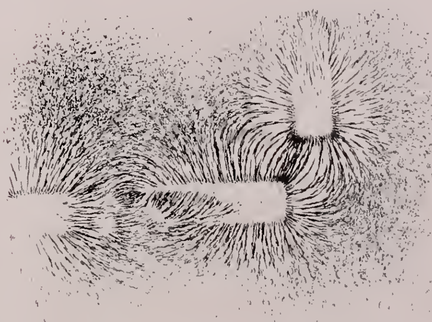

FIG. 6.—Field of Straight Bar Magnets with Axes at Right Angles and Dissimilar Poles Approached.

woody; First Vice-President, B. S. Pague, of Oregon; Second Vice-President, G. M. Chappel, of Iowa; Secretary, R. E. Kerkam, Chief of State Weather Service Division, Weather Bureau; and Treasurer, W. L. Moore, of Wisconsin.

The title, American Association of State Weather Services, was adopted by the convention, and it was decided to hold annual conventions in future at the same time and place as those of the American Association for the Advancement of Science.

The following representatives were in attendance: The U. S. Department of Agriculture, Weather Bureau, being represented by Prof. Mark W. Harrington, Chief; Major H. H. C. Dunwoody, Forecast Official; Mr. R. E. Kerkam, Chief of State Weather Service Division; Mr. N. B. Conger, Inspector, and Mr. F. J. Randolph, Stenographer. F. H. Clarke, Arkansas; J. A. Barwick, California; John Craig, Illinois; C. F. R. Wappenhans, Indiana; G. M. Chappel, Iowa; Frank Burke, Kentucky; E. A. Evans, Michigan; G. A. Loveland, Nebraska; J. Warren Smith, New England; E. W. McGann, New Jersey; R. M. Hardinge and W. O. Kerr, New York; C. M. Strong, Ohio; B. S. Pague, Oregon; H. L. Ball, Pennsylvania; S. W. Glenn, South Dakota; G. N. Salisbury, Utah; J. N. Ryker, Virginia, and W. L. Moore, Wisconsin.

Many of the representatives who were unable to be present at the convention forwarded papers, giving their views on various subjects of interest to be discussed.

The subject of instrument-shelters and a uniform manner of their exposure was debated, and it was the concensus of opinion that a uniform pattern of shelter should be adopted for use throughout the entire country. The subject was referred to a committee, consisting of Messrs. Smith, Moore and Pague, with instructions to report as to the most suitable shelter and manner of exposure to be generally adopted by State weather services.

On the subject of whether the voluntary observers should be supplied with self-registering maximum and minimum thermometers, the prevailing opinion was that such instruments should be issued, and used in determining

temperature means and averages wherever and whenever practicable. The old method of making readings at 7 A.M., 2 P.M., and 9 P.M. observations of the dry thermometer shall be continued whenever desired, but the means should be deduced from the self-registering thermometers where such instruments are in use.

As to the adoption of a form to cover the needs of a great majority of the voluntary observers who are supplied with dry or maximum and minimum thermometers and rain-gauge, it was decided to adopt a form which was suggested by the Secretary, so arranged as to admit of making three or four copies at one writing by means of the indelible carbon process, thus saving the observers the copying of the form at the end of the month; the object of this arrangement being to give a copy of the monthly report to the office of the Chief of the Weather Bureau, one to the office of the Director of the State Service, and one to be retained by the observer, and also to make such additional copies as he may desire to furnish to the local press, etc.

The forecasting of thunderstorms was the fourth subject discussed, and an interesting paper on this topic was read by the Wisconsin representative.

The proposition to print the weekly, monthly and annual reports of the State weather services in a uniform manner was freely discussed. The desirability of uniform reports was generally admitted, but it was thought impracticable at this time to take any action in the matter, as a number of States have appropriated funds for printing reports according to definite size and style.

The discussion of the question of the best methods of signaling weather forecasts by displaymen covered a wide range. The flag, the whistle, the semaphore, and the sphere, bomb, and flash-light systems were freely discussed, and an interesting paper was presented by the New England representative on the system of spherical bodies hoisted on a staff. This subject was referred to a committee composed of Messrs. Conger, Glenn and Kerkam, for report at the earliest practicable date.

On the subject of inspection of voluntary observers' stations the decision was that each voluntary station should be inspected at least once each year, to keep up the interest of the voluntary observers and to enable the directors of State services to become thoroughly familiar with each station and its surroundings. It was recommended by the association that sufficient leave of absence be granted the Weather Bureau representative at each State service centre to enable him to make a tour of inspection.

Relative to the subject, the relation of State weather services to Agricultural Colleges and Experiment Stations, it was decided that, owing to the lack of telegraphic facilities and other means of disseminating weather information, it would not be practicable, generally, to have the central stations of the State weather services at such colleges or stations, but that a very close co-operation would be desirable.

The subject of an exhibit at the World's Fair was the last general subject discussed. It was decided that each State service should have its exhibit in the building set apart for the use of the State, and not to have the exhibits collected in the building for the use of the United States Weather Bureau.

Mr. E. T. Turner, of New York, and Mr. E. H. Nimmo, of Michigan, were elected to active membership in the association, and the following honorary members were also elected: E. F. Smith, California; Prof. R. Ellsworth Call, Iowa; Chas. C. Nauck, Arkansas; Prof. Wm. H. Niles, Massachusetts; G. H. Whitcher, New England; H. G. Reynolds, Michigan; H. F. Alciatore, Oregon; Major Richard V. Gaines, Virginia; Prof. A. L. McRae, Missouri; C. F. Schneider, Michigan; Prof. Louis McLouth, South Dakota; and all active voluntary observers of the United States Weather Bureau.

After adopting resolutions of thanks to the American Association for the Advancement of Science and others for courtesies extended, the meeting adjourned *sine die*.

ROBERT E. KERKAM,

Secretary.

CORRESPONDENCE.

PATENT LAW AMENDMENTS.

Ed. Franklin Institute Journal:

The postponement to next Congressional session of Senate Bill No. 3246 affords opportunity for American inventors everywhere to examine its provisions, and, if dissatisfied with either of its eleven sections, to interrogate their respective Senators and Representatives on behalf of such modifications as they may think desirable. Section 1 especially seems worthy of their attention. Its ostensible purpose is the amendment of clause 2 of section 4887 R. S., by which, as is well known, the duration of a U. S. patent is made dependent upon that of the earliest expiring previously granted foreign patent for the same invention; but the amendment would seem to leave the most obnoxious feature of the clause substantially unchanged. Especially vexatious has the clause proved to the creators of those notable devices which, by inaugurating new arts and opening up hitherto untrodden fields of industry, constitute, to some minds, the chief justification of the patent system. If, as commonly supposed, our legistators aimed by the clause spoken of, to confer on their constituencies some kind of advantage over the foreigner, that aim has signally failed, the recoil of the weapon has proved far more disastrous than the discharge? Of patent-granting countries, ours is now admittedly foremost alike in the liberality of its patent-law and in the number and character of its useful inventions. The sum total of "aliens" prevented from exacting royalties on this side of the ocean is a mere *bagatelle* to the host of American inventors deprived, by this ill-advised clause of the revenue, of many millions that would have been drawn from the foreign user and circulated here; for it is notorious that a large majority of our inventors, rather than jeopardize their home patents, elect to forego the dangerous foreign privilege, with the result that American inventions are generally free to all except Americans. The present writer believes that the effect of the clause has been only evil and that continually and that the only proper amendment is to *expunge it*, or if that may not be, then let *American* ingenuity at least be relieved of this unmerited and unpolitic burden.

GEO. HENRY KNIGHT.

Northampton, Mass., August 12, 1892.

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIV. OCTOBER, 1892. No. 4

FISKE'S ELECTRICAL RANGE FINDER.

[*Report of the Committee on Science and the Arts.*]

[No. 1,655.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 1, 1892.

The Sub-Committee of the Committee on Science and the Arts, to whom was referred for examination

FISKE'S ELECTRICAL RANGE FINDER,

respectfully report that: The said invention is the subject of United States Letters-patent Nos. 406,829, 406,830, 418,910 and 444,217, granted to Bradley Allan Fiske, Lieutenant United States Navy.

These patents cover a new method of finding the range and position of a distant object quickly and with sufficient accuracy for directing guns on a distant target, either from a man-of-war or harbor fortification.

In naval warfare at the present day, where the ships are equipped with long-range guns of large calibre and the hulls lie so low in the water that they present an inconspicuous surface for a target, and the powerful engines with which they are propelled enable them to change their position rapidly, the necessity for some approximately accurate method of promptly determining the distance of the enemy's ship is an urgent one. In the language of one of the most distinguished officers of the British Navy: "No one knows what will happen in a naval action now, no chance should be thrown away. In these days, where it is possible for one shot to win an action, a ship fitted with an accurate range finder must have an enormous advantage over a ship not so fitted."

Prior to Lieutenant Fiske's invention, no satisfactory way of determining the distance of the enemy's ship had ever been devised. Many methods had been suggested and practised, but all were open to the objections:

(1) That the observations from which the calculations were made were not accurate enough.

(2) That the positions were changed by the time the calculations were completed.

To meet the latter objection it was customary to assume the position where the target would be by the time the calculations would have been completed; this introduced a new source of error. The method usually adopted was to station one observer at each end of a base line of known length to obtain by observation the angles at their respective ends between the base line and the object to be fired at, the observers communicating to each other either by visual or telegraphic signals; with the two angles thus observed and the known base line the distance from either observer could be calculated. Another method was to make a calculation of the time required for the sound of a gun fired from the enemy's ship to reach the observer. Small tubes, filled with sand, like hour glasses, which would register in seconds, were turned at the moment of observing the puff of smoke; the number of seconds elapsing between the puff and the report multiplied by the known

velocity of sound would give, roughly, the distance. It is obvious that after the second or third shot such a method would be valueless, as it would be impossible to identify the puff with a report.

A third method was to send an observer to the mast-head with a sextant to find the angle between the horizontal plane passing through the sextant and the line joining the sextant with the object whose distance was to be measured. From tables the distance corresponding to this angle was given to the captain of the gun.

The problem has been solved in a most interesting way by Lieutenant Fiske, who has made a most ingenious application of an electrical principle in the construction of his apparatus. The method, briefly stated, is as follows: Two observers are stationed at the ends of a base line of known length; each observer directs a telescope pivoted at the end of the base line upon the object whose distance is to be measured; the lines of sight of these telescopes will then correspond respectively with the two sides of a triangle of which the known base line is the base; by the movement of these telescopes the needle of a galvanometer is made to move over a scale, and a third observer, stationed at any convenient point (say at the gun, or in the chart room), reads off the length of one of the sides of the triangle in feet, the distance sought.

The principle of the invention consists in first determining a fractional portion of a conducting body bearing in length a ratio to the angle included between two lines of sight directed upon a distant object, and second, measuring the electrical resistance of said length. This is accomplished automatically, and the result given, as above stated, by means of an apparatus which is practically a Wheatstone bridge, the variable resistances in the members of which are arcs upon which move sliding contacts corresponding with the movements of the telescopes.

The following full description of the operation of the instrument is taken from Patent No. 444,217:

Referring to the accompanying *Fig. 1*, let *A B* be a base line and *T* the position of a distant object, the range of

which $A\ T$ is to be determined by trigonometry. In the triangle $A\ T\ B$,

$$A\ T = \frac{A\ B \times \sin A\ B\ T}{\sin A\ T\ B}$$

let C and D represent two telescopes or alidade arms, pivoted

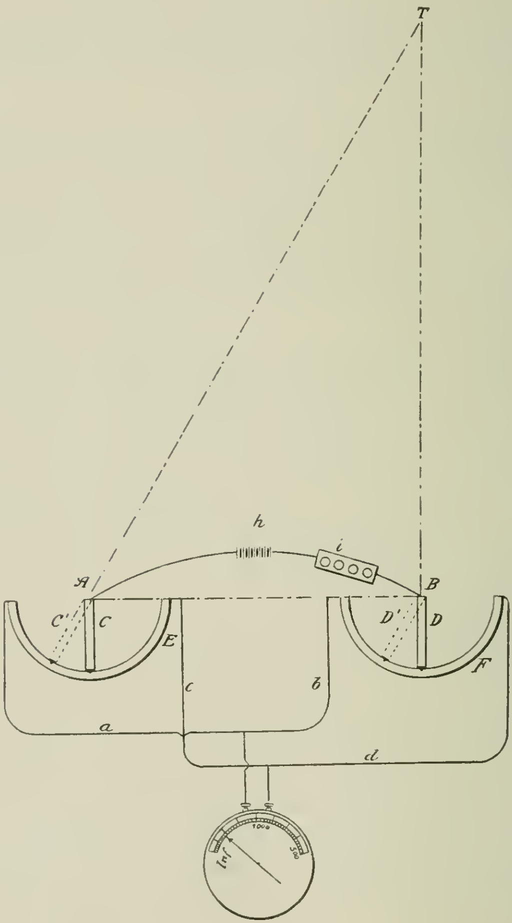

FIG. 1.

at the points A and B and sweeping over arcs E and F, of conducting material, the said arcs having their extremities upon the base line $A\ B$. Let the telescope C be directed upon the point T, assuming the position represented by C', dotted

lines. Then, obviously, the angle $C' A C$ is equal to the angle $A T B$, and the portion of the arc E included between the positions C' and C of the telescope will measure the angle at $A T B$.

In the foregoing formula the base line $A B$ is known by measurement and the angle $A B T$ is, as shown in the figure, a right angle, then the $\sin A B T$ becomes unity. It remains, therefore, to find the angle $A T B$ in order to determine the distance $A T$, so that it becomes necessary to provide a simple and rapid means of at once determining what the angle $A T B$ is. To this end the arcs $E F$ of conducting material are connected in a Wheatstone bridge, the four members of which are shown, respectively, at $a b c d$. In this bridge a galvanometer g is connected in the usual way, and also the battery h, the terminals of the battery wire being connected to the telescopes at their pivot-points $A B$, so that the circuit proceeds through the telescopes to the arcs, and then at the arc F divides through the wires $b d$ and at the arc E divides through the wires $a c$. It will be plain that when the two telescopes C and D stand at right angles to the base line, and hence parallel to one another, the bridge will balance and the galvanometer will show no deflection. The lines of sight of the two telescopes then being parallel the galvanometer will indicate infinite range; and of course this will be true no matter where the telescopes may be on their respective arcs, so long as their lines of sight are relatively parallel. But if one telescope be moved out of parallelism with the other—as, for example, the telescope C moved to the position C'—then clearly the bridge will be thrown out of balance and the galvanometer will be deflected. It will also be clear that the extent of deflection of the galvanometer will depend upon the length of arc included between the two positions of the telescope $C C'$, and will be greater as that arc increases, so that with a battery with constant electro-motive force it becomes possible to determine the extent of movement of the telescope C, by simply observing the indication of the galvanometer. It will of course be obvious that, as the angle between the positions C and C' of the telescope increases, the length of

the line $A\ T$ will constantly decrease, while the deflection of the galvanometer will constantly increase, so that the galvanometer indicated ranges starting from infinity when the galvanometer shows no deflection, small ranges being indicated by large deflections of the galvanometer, and vice versa. As a matter of convenience, it is preferred to employ for this purpose a galvanometer so constructed that the deflections of the index will be proportional to the difference of potential at the terminals. The observer instantly reads the range from the galvanometer which is provided with a scale suitably marked in linear units, such as yards.

If, however, the angle $A\ B\ T$ is not a right angle, then the factor $sin\ A\ B\ T$ must be taken into consideration in solving the formula

$$A\ T = \frac{A\ B \times sin\ A\ B\ T}{sin\ A\ T\ B}$$

or, in other words, the observer at the galvanometer may simply multiply the range indication by the $sin\ A\ B\ T$ numerically expressed in order to reduce the indicated range to the true range. The angle $A\ B\ T$ is observed directly on the arc F.

In the above demonstration the resistance of the whole circuit is assumed to be constant or remains the same as when the two telescopes stand parallel to each other and touch the middle part of their respective arcs. As a matter of fact, however, the resistance of the whole circuit decreases as the telescopes approach the extremities of the arcs; this variation in resistance due to change of position will affect the total resistance in circuit to an extent depending upon its ratio to the resistance of the whole circuit. If this ratio be made very small, the variation may be rendered inappreciable. This is easily done by the insertion of a high resistance in the battery loop at I between the points A and B. The resistance of the galvanometer has been neglected, and it has also been assumed that the electro-motive force and internal resistance of the battery, and the resistances of the various contacts remain constant. While this is not theoretically true, it is found

that by using storage batteries and making the contacts carefully no appreciable error is introduced.

Communication between the two observers, which is necessary to secure a simultaneous observation, is secured by a telephone, the transmitter and receiver being attached to the telescope in proper positions for the mouth and ear while the eye is employed in aligning the telescope. An electric bell attachment is also provided, so that when the vessel is rolling "snap shots" may be taken; that is, the observer at *A* when he has aligned his telescope on the object will close the bell circuit at his end, then when *B* has his instrument correctly aligned, he will touch the button and both bells will ring, and the telescopes will rest until a reading has been made of the galvanometer, which is placed at any convenient point, like the chart room, or conning tower. The range being known and communicated to the person in charge of the gun, he can at once give the piece the proper elevation.

Trials have been made of the instrument during the past two years on vessels of the United States, French, Italian and Russian navies. These tests have been carefully conducted under the authority of the respective governments, and the results as reported by the officers in charge have demonstrated that the invention is a very great improvement over the methods formerly in use. The first installation was made upon the U. S. S. *Chicago*, and observations were made from that vessel while moored at the wharf at the New York Navy Yard upon prominent objects in the harbor. Two base lines were used, in length, 200 feet and 44 feet, respectively. The distances measured ranged from 940 to 1,325 yards. The mean of errors with the long base line was 0·6 per cent., and with the short base line 1·9 per cent.

Better instruments were installed on the U. S. S. *Baltimore*, and after a six months' trial at sea an official report was made, which showed very satisfactory results. The base line was ninety-three yards long. The telescopes were screwed down on the centre line of the deck. One galvanometer was placed in the conning tower and the other on

the bridge. The telescopes were adjusted by sighting them on the moon, which being practically at an infinite distance laid them parallel, and the galvanometer stood at zero. Trials were made in various harbors of Europe while the vessel was lying at single anchor, rolling and swinging; the observations were compared with the positions plotted on the chart, and the variations from the true distance were found to be slight. In the harbor of Spezia, Italy, with the ship lying directly between a fort and a lighthouse, observations were made upon both objects. By adding together the distance from the ship to each object by range finder, and comparing the sum with the distance between the objects as shown by the chart, the error of the range finder was shown, and the uncertain position of the ship as it swung at anchor was eliminated. The mean of twelve observations to the fort and seven to the lighthouse was taken, and showed an error of only one-half per cent.

Good results were obtained at target practice off the harbor of Villa Franche. There was a gentle breeze and the ship rolled slightly. Two targets were shot away and the floating barrels and planks of which they were formed were frequently hit. But few wild shots were made, and the first shots were about as good as the last. The rolling of the ship did not materially affect the reading of the needle, and the shock of the discharge had no effect upon the instruments. The Board reported that reliable results were obtained within three per cent. in ranges less than 5,000 yards, and that the observations may be made by any two sailors after a little instruction and practice.

This result is practically the same as that obtained on the ship *Formidable* of the French Navy which showed the average of errors in distances between 800 and 4,500 yards to be about three per cent. The official report of the trial states, however, that the errors are due more to inaccurate observations than to the electrical apparatus; greater accuracy might be obtained also by using a galvanometer with a larger scale, so that closer readings could be made.

A commission of five officers of the Italian Navy made trials of the range finder on board the ironclad *Terribile*, under

all possible conditions at sea in the Mediterranean nea Spezia, Italy. The official report states that the instrumen has positive merit and can render most useful service, being ingenious, practical and of most easy management.

The results obtained in this practical way have established the value of the invention, and other vessels of the United States Navy are now being equipped with the Fiske range finder. It is not alone, however, in marine warfare that the instrument may be used to advantage; it has even greater capabilities when used in fortifications commanding harbors and adjacent waters. There base lines of any desirable length can be secured, and observers may be sta

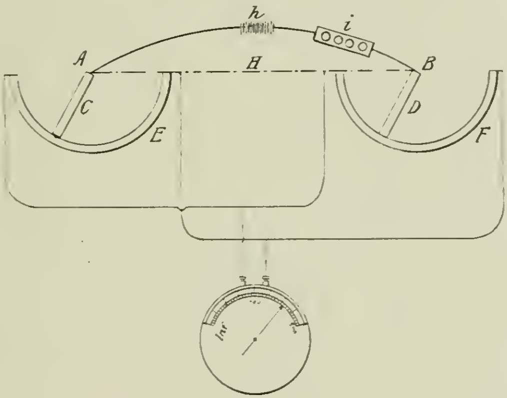

FIG. 2.

tioned at the most advantageous points, while each group of guns may be directed by the officer in command, who may concentrate the fire of them all upon a single ship, or fire at different ships, as his judgment may dictate.

For this service the position finder is equally necessary with the range finder. This instrument shows the direc tion or bearing of the object, which though visible from the ends of the base line, may be concealed by smoke or fog from the gunners. In principle the instruments are the same. A second galvanometer is connected to the same conducting arcs as the range finder, but differently, the connections being so made that the deflections of the needle depend upon the sum of the angles through which the telescopes

are moved from the zero position. The deflection of the needle shows the angle which a line joining the object aimed at and the centre of the base line makes with the base line. If, therefore, the guns are placed near the centre of the base line, they can be directed upon the target, even though the latter is not visible from the guns.

Fig. 2 illustrates the method of connecting the galvanometer for the range finder, *Fig. 3* the connections for the position finder.

In view of the ingenuity displayed in the invention and the great advance it makes in securing a more effective ser

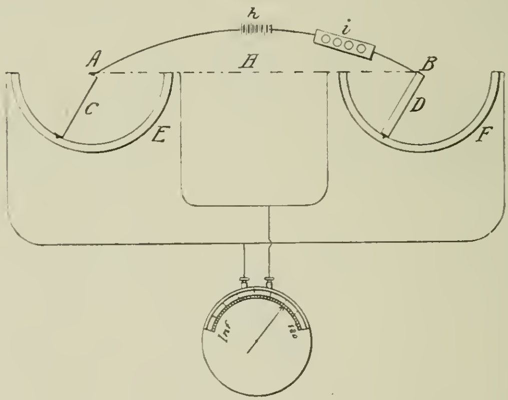

FIG. 3.

vice of heavy ordnance, your committee feel justified in recommending the award of the Elliott Cresson Gold Medal to the inventor.

E. A. SCOTT, *Chairman*, CARL HERING,
CLAYTON W. PIKE, L. F. RONDINELLA,
C. BILLBERG.

Adopted, June 1, 1892.

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

ECONOMICS OF "AUTOMATIC" ENGINES.

By R. H. Thurston.

The "automatic" steam engine is a form which, though a generation old, has come into very general use only within a few years, and mainly since the demands of electric lighting have been so exacting in the matter of regulation. In earlier days, a variation in speed of five per cent. or more from the mean, in many applications of steam-power, was perfectly admissible; and even in the most exigent of work, that of cotton mills making "fine goods, two per cent. variation was thought about the limit of practical attainment and very satisfactory. It is now considered that a range of one per cent. from the mean is too great for the purposes of the electrician, and, so far has invention and improvement extended, it is possible to secure a guarantee, from makers of the later forms of the "automatic" engine, that no variation shall take place though the load be thrown off entirely and at once completely restored; while, with some constructions, it is actually practicable to make the machine assume a higher speed with full load than with none. This is an incidental result of the attempt to meet the requirements of modern engineering; which requirements compel a complete revolution in the type of engine formerly most familiar to us.

The greater part of the machinery to be driven by these engines, as constructed by the electrician and engineer, calls for a small amount of power and a very high speed of rotation. The armatures of standard forms of dynamo-electric machines ordinarily range from speeds of 1,000 to 3,000 revolutions per minute; though special constructions are brought down to a fraction of these figures. The power is from ten to forty or fifty horse-power in common distributions and up to as high as 250 for the largest single dynamos; although, often, the dynamos may be so grouped that from 500 to 1,500 horse-power may be taken from one

engine. It is not yet possible, in all cases, to determine whether a large single engine or several smaller machines of similar aggregate power is best; but the demand for the small engine of from twenty-five to 100 horse-power is enormously great, and the manufacture of this class of engine has been immensely stimulated by the comparatively recent developments of systems of production and of distribution of electric energy. These machines are commonly of the class here denominated "automatic," are 'high-speed" engines of a modern and special type, and are characterized by a "positive" valve-gear, as distinguished from the older and more familiar forms of "trip cut-off" or detachable gear, with regulation by a governor which determines the point of cut-off by, usually, shifting an eccentric, as years ago employed by Hartnell and by Hoadley, and this engine is built to operate at a speed seldom less than 200 revolutions a minute, and often above 300. The positive motion, as a valve system, and the shaft-governor, are necessary consequences of the demand for high speed of rotation and nice regulation; the latter being, in fact, a more essential matter than the former, and one which has compelled many modifications of the details of construction of the older forms of engine to secure satisfactory uniformity of motion. The characteristics and the essentials of each type are now so familiar to all that it is unnecessary for present purposes to describe them in detail. An "automatic" engine has come to be defined as one in which these methods of construction have been adopted and which, having a positive valve-motion and firmly connected governor, adjusts its power to its load automatically through the latter. The definition logically applies quite as well to the Corliss and Greene and similar detachable systems of valve-gear; but convention seems to confine it to the later high-speed engine.

The modern automatic engine, at its high speed of rotation, brings into play the forces of inertia to an extent never observed in the older machine, and its design must usually be modified somewhat to insure smooth working by the introduction of compression and counter-balancing to a

correspondingly greater extent, and with much greater care than formerly. This means increased clearances, as compared with the other type, and often heavier running parts, adjusted as to weight in the manner first practised by Porter, as well as the long familiar counter-balancing. The Porter system gives more perfect adjustment of pressure on the journals. and the last gives insurance against shake of the engine, as a whole, on its foundations. These dynamic actions and adjustments have been the subject of many and extended investigations, both mathematical and experimental, and the result has been admirable success in the improvement of the standard engine of the time, in this respect, and beautifully smooth running, where intelligence and experience have conspired in design and construction. It is proposed to consider the economics of such an engine, assuming it to represent the best contemporary practice in these respects, and to be ready for operation under at least ordinarily favorable conditions. The exact expenditure of heat, steam and fuel under specified representative conditions of this case, including steam-pressure, back-pressure, ratio of expansion, and boiler-efficiencies, can be computed for the thermo-dynamic, ideal case; and, knowing the magnitude and conditions of physical operation of the engine, friction included, its wastes of energy, whether thermal or dynamic, can be very closely obtained by computation, and these wastes being added to the total thermo-dynamic expenditure, the gross outlay of energy becomes known and the economical problem can be solved. The following is an illustration of these facts, as determined for an "automatic" simple condensing engine, rated at ten to fifteen horse-power; having a cylinder six inches in diameter and eight inches stroke of piston, its speed 280 revolutions a minute, and the machine proportioned for a steam-pressure of 100 pounds, though strong enough to be driven, if necessary, with a much higher, perhaps, with little risk, at fifty per cent. higher pressure. Compression is complete and leakage insensible.

It is proposed to compute the demand for heat and steam for the purposes of designer and purchaser, on the assumption-

tion of the date given below, the conditions as to waste being substantially those illustrated in the Sandy Hook experiments of 1884. Pressures are taken from seventy-five to 155 pounds per square inch above the atmosphere; ratios of expansion from 1·6 to 16, and the engine as speeded at 280. External wastes of heat are assumed to average 0·5 b. t. u. per square foot of external surface and per degree range of temperature from atmospheric—here taken as 100° F. Internal wastes are taken as aggregating, as a fraction of the total steam supplied,

$$w - a / d. \sqrt{r\,n}$$

where the coëfficient $a = 4$ in the case assumed to be fairly represented of that here considered; d is the diameter of cylinc. in inches, r the ratio of expansion, and n the number of revolutions per *second*. This simple expression will probably answer present purposes, in the absence of a more exact and better established one. Friction wastes are taken as found for short cut-offs, efficiency of the engine as a machine being assumed at 0·85. Better work than this can be and should be done. J is taken as 778. The following are the assumed data:

DATA.

$p_1 =$	75	95	115	135	155′
$p_3 =$	5	5	5	5	5
$r =$	1·6	2	4	8	16
$c = \frac{1}{r} =$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$

Pressures are here measured from absolute zero.

The work per cubic foot of steam is here computed by the familiar expressions of Rankine:

$$U D_1 = J D_1 \left\{ T_1 - T_2 \left(I - loge \frac{T_1}{T} \right) - \frac{T_1 - T_2}{T_1} l_1 - r(p_2 - p_3) \right.$$

and

$$p_2 = U D_1 / r.^*$$

The results of these computations, as made and checked

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* *Rankine's Prime Movers; Thurston's Manual*, p. 398.

r	Cut-off.	Pressure, Pounds per Square Inch.	Temperature Absolute. T_1.	Density of Steam.	Latent Heat, Foot-Pounds.	Terminal Pressure, Pounds per sq. in.	Terminal Pressure, Pounds per sq. ft.	Temperature. T_2.	Indicated Power.	Steam per I.H.P. per Hour (Ideal) W'	Internal Waste Coeffic $\frac{a}{d}\sqrt{r}/n$	Internal Waste, Pounds per I.H.P. and per Hour	External Waste, Pounds per I.H.P. and per Hour.	Total Waste, Pounds per I.H.P. and per Hour.	Total Consumption, Pounds per I.H.P. and per Hour.	Same per D.H.P.
16	1-16	75	768·6	·175622	110,437	3·22	463·7	605·4	3·100	*15·85*	1·234	19·56	3·30	22·86	38·71	*45·54*
8	1/8	75	768·6	·175622	110,437	7·08	1,020	638·6	6·42	*15·32*	·87287	13·37	1.50	14·93	*30·25*	*35·58*
4	1/4	75	768·6	·175622	110,437	15·55	2,239	676	11·77	*16·72*	·61720	10·32	·847	11·167	*27 887*	*32·80*
2·7	3/8	75	768·6	·175622	110,437	24·29	3,498	699·7	14·97	*18·48*	·50710	9·88	·666	10·546	*30·026*	*35·32*
2	1/2	75	768·6	·175622	110,437	34·15	4,918	719	17 85	*21·41*	·43650	9·71	·555	10·265	*32·51*	*38 24*
1·6	5/8	75	768·6	·175622	110,437	44·00	6,336	734·2	19·90	*24·76*	·3900	9·66	·502	10·162	*34·92*	*41·08*
16	1-16	95	785·1	·219430	151,336	4·08	588	615·0	4·83	*12·71*	1·234	15·73	1·663	17·393	30·133	35·45
8	1/8	95	785·1	·219430	151,336	8 97	1,292	649·4	9·31	*13·21*	·87287	11·53	·969	12·499	*25 71*	*30·24*
4	1/4	95	785·1	·219430	151,336	19·70	2,837	688 4	15·97	*15·42*	·61720	9·09	·366	9·656	*25·076*	*29·50*
2·7	3/8	95	785·1	·219430	151,336	30·77	4,431	713	20·58	*17·72*	·50710	8·99	·428	9·418	*27·14*	*31 93*
2	1/2	95	785·1	·219430	151,336	43·26	6,229	733·1	24·20	*20·34*	·43650	8·88	·375	9·255	*29·595*	*34·81*
1·6	5/8	95	785·1	·219430	151,336	55·72	8,024	749	26·62	*23·11*	·3900	9·02	·333	9·353	*32 46*	*38·19*
16	1-16	115	790·1	·262732	179,142	4·94	711·8	623·0	6·18	*11·91*	1·234	14·70	1·360	16·060	27·97	32·91
8	1/8	115	799 1	·262732	179,142	10·86	1,564	658·4	11·62	*12·68*	·87287	11·07	·755	11·825	*24·55*	*28·82*
4	1/4	115	799·1	·262732	179,142	23·84	3,433	698·6	19·68	*14 97*	·61720	9·24	·415	9·655	*26 48*	*28 97*
2·7	3/8	115	799·1	·262732	179,142	37·25	5,364	724	25·28	*17·35*	·50710	8 80	·331	9·131	*28·836*	*31·15*
2	1/2	115	799·1	·262732	179,142	52·36	7,540	745	29 64	*19·88*	·43650	8·68	·276	8·956	*3*	*33.92*
1·6	5/8	115	799·1	·262732	179,142	67·46	9,714	761·5	32·60	*22·60*	·3900	8·82	·251	9·071	*31·67*	*37·26*
16	1-16	135	811·2	·305659	206,286	5·8	835·6	630·0	7·534	*11 38*	1·234	14·05	1·043	15 093	26·473	31·14
8	1/8	135	811·2	·305659	206,286	12·75	1,836	666·2	13·91	*12·32*	·87287	10·75	·504	11·314	*23·63*	*27.80*
4	1/4	135	811·2	·305659	206,286	27·99	4,031	707·6	23·37	*14·67*	·61720	9·05	·344	9·394	*24 06*	*28·30*
2·7	3/8	135	811·2	·305659	206,286	43·73	6,297	733·9	30·00	*16·96*	·50710	8·60	·263	8·863	*25·82*	*30·37*
2	1/2	135	811·2	·305659	206,286	61·47	8,852	755·3	35 00	*19·54*	·43650	8·53	·226	8·756	*28·29*	*33·28*
1·6	5/8	135	811·2	·305659	206,286	79·19	11,403	772·4	38 50	*22·25*	·3900	8 68	·208	8·888	*31·13*	*36·62*
16	1-16	155	822	·348265	232,738	6·66	959.4	635·80	8·89	*10·98*	1·234	13·55	·836	14·336	25· 6	28·84
8	1/8	155	822	·348265	232,718	14·63	2,106	673·0	16·20	*12·05*	·87287	10 52	·462	10·982	*23 03*	*27·09*
4	1/4	155	822	·348265	232,738	32·14	4,628	715·3	27·00	*14 41*	·61720	8·29	·274	9·164	*23·57*	*27·73*
2·7	3/8	155	822	·348265	232,738	50·2	7,223	742·3	34·58	*16 72*	·50710	8 48	·213	8·693	*25·41*	*29·89*
2	1/2	155	822	·348265	232,738	7[illegible]·58	10,163	764·5	40·50	*19·28*	·43650	8·41	·182	8·592	*27·87*	*32 74*
1·6	5/8	155	822	·348265	232,738	90·92	13,092	782	44·48	*21.95*	·3900	8·57	·164	8·344	*30·68*	*36·26*

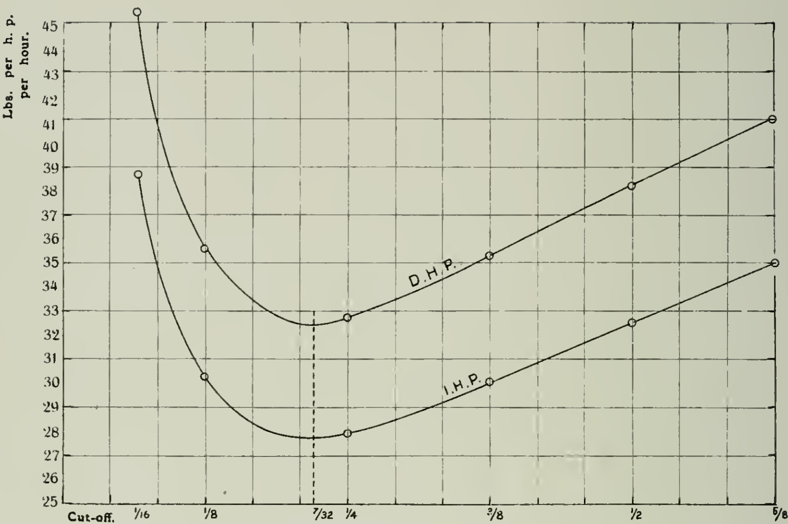

Fig. 1, Economy at 75 lbs. Pressure.

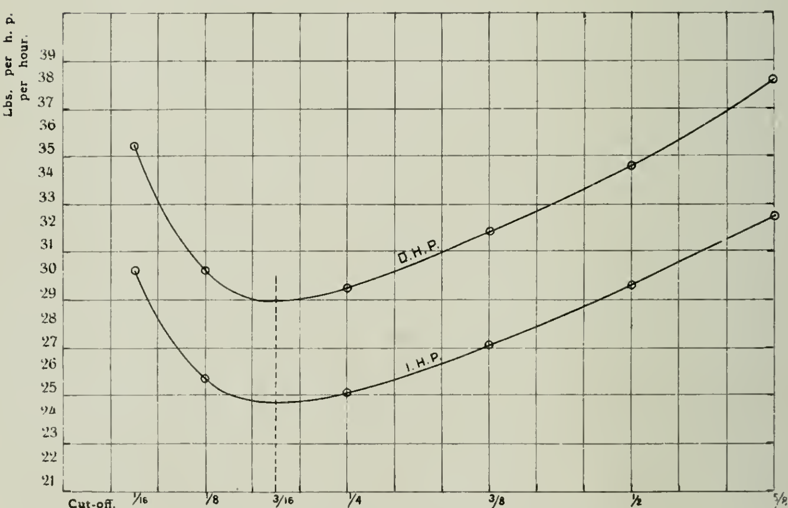

Fig. 2, Economy at 95 lbs. Pressure.

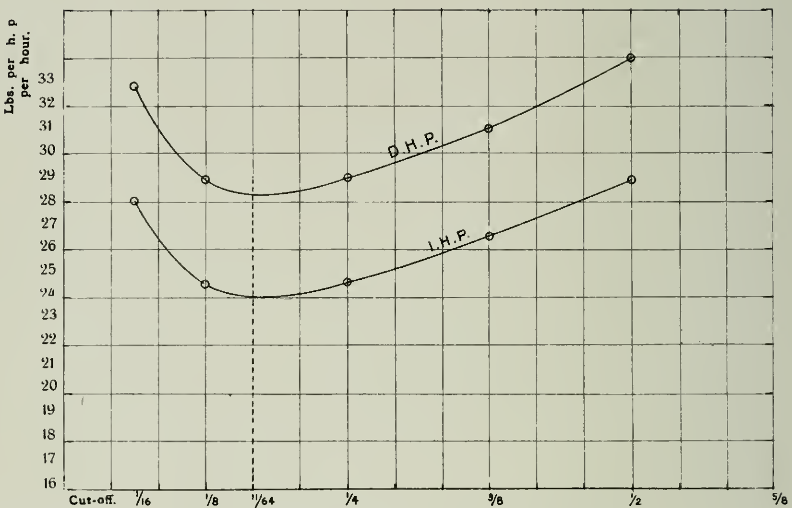

Fig. 3, Economy at 115 lbs. Pressure.

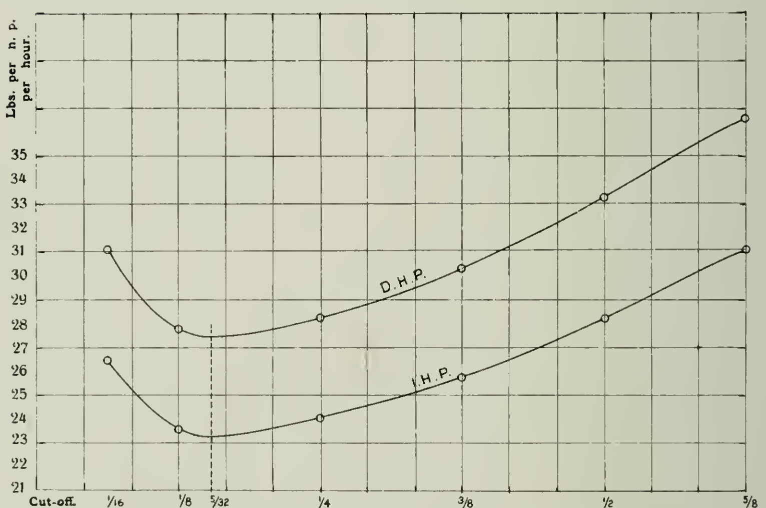

Fig. 4, Economy at 135 lbs. Pressure.

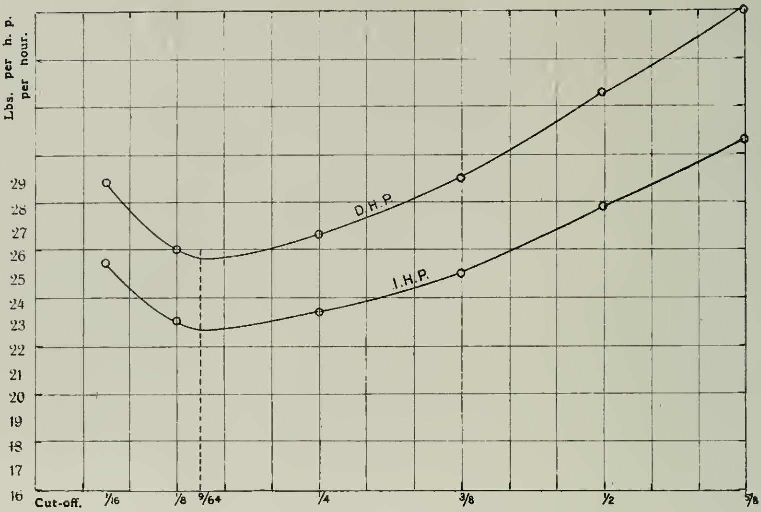

Fig. 5, Economy at 155 lbs. Pressure.

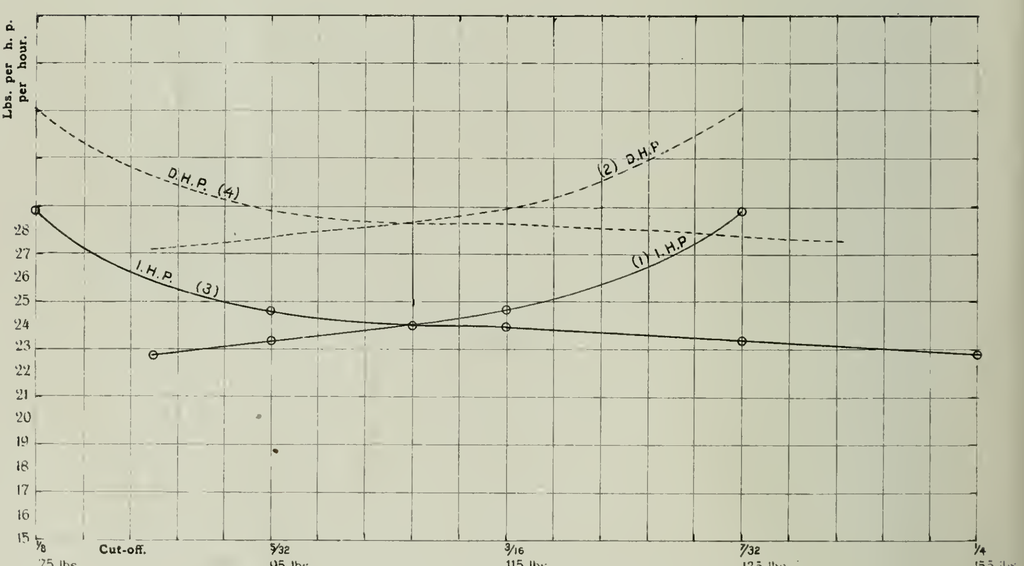

Fig. 6, Economies with varying Pressures.

by Messrs. C. B. Auel, A. R. Henry and F. P. Ide, following the methods prescribed by the writer, are presented in the accompanying table.

An examination of the figures here collected will show in a most interesting manner the gradual variation of steam consumption with change of expansion at each pressure and a comparison of the figure for the several pressures wil illustrate the interesting modifications of result due to variations of expansion with pressures, and the differences in the location of the best points of cut-off for these pressures. These instructive comparisons are best made by the construction of curves, of which the coördinates are, for each pressure, weights of steam demanded per horse-powe and per hour at stated ratios of expansion. Such curve have been drawn by the computers for the present case, and are illustrated in the accompanying plates. It is seen that at the lowest pressure, 75 pounds, maximum economy o steam and fuel is attained at a cut-off very near $\frac{7}{32}$, or a ratio of expansion of about 4·5, when the dynamo-metric power is taken, or at about a cut-off of 0·2 and $r = 5$, on the basis of indicated power. These figures become about 3·16 and 5 at 95 pounds, $\frac{11}{64}$ and 6 at 115, $\frac{5}{32}$ and 6·4 at 135, and $\frac{9}{64}$ and 7 when the pressure becomes 155 absolute, or 140 pounds by gauge.

This gradual shifting of the ratio of expansion giving highest economy of fuel and of steam is better illustrated in the last set of curves in which two exhibit the variation of this point of cut-off with varying pressures, while the other pair show the progressive gain in economy of fuel and of steam in a similar manner; the numerical values of the former quantities increasing, and the latter decreasing with rising steam-pressure. The weight of steam consumed is not far, at best, from

$$w = 250 / \sqrt{p}$$

pounds of steam per hour per indicated horse-power, when working under best conditions, and the best ratio of expansion, on the same basis, is about

$$r = 0·5 \sqrt{p}$$

The conditions here assumed may be taken as fairly representative of good practice with such an engine. Where leakage occurs, or when compression is incomplete and the clearances thus become sources of additional wastes, these figures may be much exceeded. Experiments with an engine of such dimensions and proportions as are here assumed, as made under the eye of the writer, have given internal wastes through these faults of construction and of operation, amounting to three times that here found, and bring the expenditures of steam and fuel up much higher figures. Those here obtained, however, correspond with working conditions which can probably always, with care, be obtained in the actual case, and may serve as a guide in the designing or the selection of such engines for use. Larger engines will be less subject to such wastes, and the margin between the ideal case and the actual, may be thus reduced approximately in proportion to increasing size of engine. The economically desirable ratio of expansion and point of cut-off, however, is always somewhat less than that found to give lowest expenditure of steam and fuel, since every item of cost in the construction of the engine involves a corresponding annual charge thereafter, and a compromise between increasing annual expense on this count, and decreasing cost of fuel must be made to secure the best results.

The commercially desirable ratio of expansion is always less than that giving maximum duty; but the margin between the two depends greatly upon the relative costs of construction and of operation of engine and boiler and cost of fuel. Methods of exact computation are becoming developed and approximate methods are well-known.* In general, at the commercial centres, the ratio to be adopted in designing will not be far from two-thirds that here found to give best effect for the ideal case, twenty per cent. lower than is shown on the diagrams for the actual case, and still lower where it is sought to make the most out of an engine already set and in operation.

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* *Manual of Steam Engines*, Vol. I, Chapter VII.

The mean effective pressure here found is seen to be not far from

$$p_2 = 6 \sqrt{p_1}$$

and the pressure to be adopted by the designer for such cases will be greater, perhaps not far from

$$p_1 \doteq 5 \sqrt{p_1} \text{ —}$$

gauge-pressures being here taken while the power of the engine is seen to be approximately

$$I. H. P. = 0{\cdot}03\, d^2 \sqrt{p_1}$$

nearly and slowly rising with increasing pressure. Had the wastes of the engine been larger, which is oftener the case than the opposite, the cut-off would be deferred, the ratio of expansion lessened, the mean effective pressure increased and the relative power for a given size of engine increased, since in such cases, the gain by reduction of wastes more than offsets the thermo-dynamic gain by the reverse process of increasing the ratio of expansion. The figures here obtained may be taken as representing the limit of expansion in the case of the best makes of automatic engine, under best conditions of operation. In the usual case, a lower ratio of expansion and larger mean pressure will be desirable.

THE AËRATED FUEL COMPANY'S SYSTEM OF BURNING OIL BY COMPRESSED AIR.

By W. S. Collins.

[*Abstract of a paper read at the stated meeting of the Institute, held June 15, 1892.*]

Jos. M. Wilson, President, in the chair.

Mr. Collins: The advantages of oil as fuel seem to have occurred to those engaged in handling the article, in this country, very soon after its discovery in Western Pennsylvania, as there are accounts of its use, in a crude way, under boilers more than twenty-five years ago. The number of plans devised for burning this liquid fuel, and the number of patents issued for them, are very large; but it is only within the last seven or eight years that a method has been devised for burning oil in a way to meet all the requirements of the different kinds of fire required in various lines of mechanical work. What are these requirements? We shall not attempt to describe each kind of fire in detail, but generally the requirements of a perfect oil fire are:

(1) That it shall be capable of giving the varying degrees of heat required in each line of work, and be subject at all times to the instant control of the workman.

(2) That it shall produce complete combustion, leaving no smoke or smell.

(3) That it shall be entirely free from sulphur or other impurities.

(4) That it shall be capable of being made a more or less oxidizing flame.

(5) That it shall be as safe as, if not safer than, a coal or wood fire.

(6) Last, though not least, that it shall be at least as cheap, in cost of fuel, as coal or wood.

The experiments which have been made to obtain these results may be divided into three general classes: In one

a retort or system of retorts is employed to convert the oil into gas before it is burned. This plan demands, in nearly every instance, the use of more or less complicated apparatus, or necessitates a special arrangement of the fire box, which unfits it for service in the event of the stoppage of the gas generating device.

Another class uses steam, or steam and air, to atomize the oil. The objection to every steam-jet burner is that it cannot be successfully used in all kinds of work, as it is difficult to get the highest degrees of heat when steam is mixed with the oil, and the heat from a steam-jet burner cannot be perfectly regulated nor made subject to instant control.

The third class relies upon air alone to atomize the oil. This is done in two ways: One is by spraying the oil, which is allowed to run out on the tines of a fork in the burner, by means of air under six or eight ounces pressure from a fan blower.

The chief objections to this system are:

(1) That it is of necessity a gravity system; that is, that the oil must be at some point a little higher than at the point of combustion, in order to enable it to flow to the burner, as six or eight ounces pressure from a fan blower is not sufficient to lift the oil to the burner, as is done where air under ten or fifteen pounds pressure is applied to it.

(2) That it requires more power to run a fan blower, to spray a given amount of oil, than it does to run an air compressor to spray the same amount.

(3) That a fan-blast burner, as has been shown by repeated independent tests, consumes nearly one-third more oil for a given amount of work than the compressed air burners.

The other air-spraying system is to subject the oil to sufficient pressure, to lift it from the storage tank, placed below the point of combustion, to the tip of the burners, where it is met by the air under the same pressure and driven into the fire, through an orifice, varying from one-thirty-second of an inch to five-eighths of an inch in diameter, in a fine spray. It is this compressed air system,

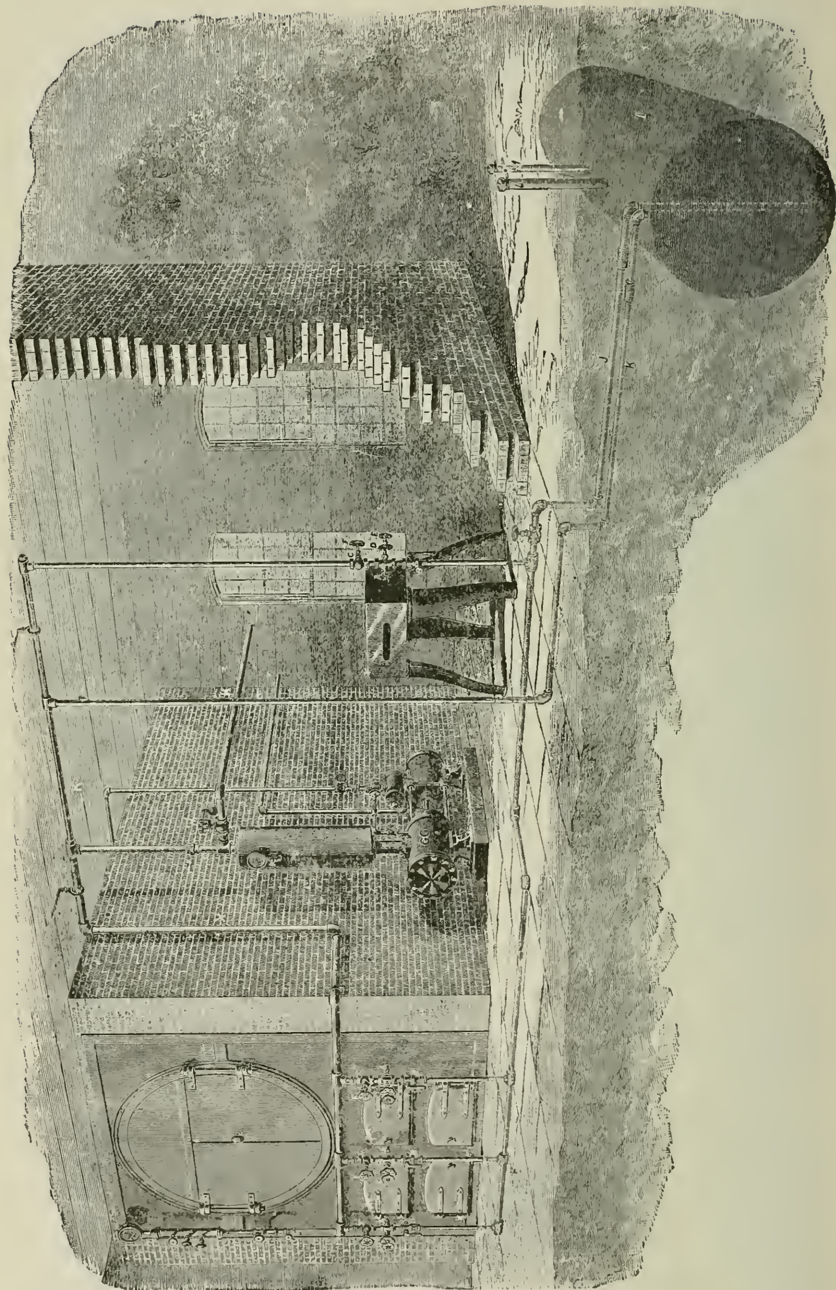


FIG. 1.

devised and patented about seven or eight years ago, and since then gradually perfected by James H. Bullard, of Springfield, Mass., and now owned by the Aërated Fuel Company, that we propose to describe more fully in this paper.

The diagram (*Fig. 1*), here shown, represents a small plant arranged according to this system. *G G* is an air compressor, which may be called the heart or life of the system. The compressor may be run either by a belt from shafting or better by steam direct from the boiler, as shown in the diagram. *Fig. 2* shows a duplex steam-actuated air compressor. The air, compressed usually to about fifteen pounds to the square inch, passes into the air receiver shown on top of the compressor. This equalizes the pressure and eliminates the pulsations of the air compressor. The governor on the air compressor allows no more steam to be taken than is needed for the number of burners in use at the pressure required. From the receiver the air passes through the main air pipe *K*, down to the tank containing the oil, which is always placed below the level of any of the fires. As this tank is made air tight, the pressure of the air on the surface of the oil forces it through the main oil pipe *J* to the only outlet which it can find, namely, at the tip of each burner *A*, on the small oil pipes extending upward from the main pipe *J* to each burner. It will be noted that the main air pipe *K*, besides being connected with the oil tank, extends by small branches to the top of each burner *A*, and meets the oil which is conveyed through a small pipe in the interior of the burner to a point very near its tip. Exterior and interior views of the burner are shown in *Figs. 3* and *4*. The air in the burner surrounds the small oil pipe so that when it meets the oil at the tip of the burner it strikes the oil on all sides and mingles with it, thus forcing the oil from the tip of the burner in a fine spray. This spray, looking like a jet of water, extends four or five inches from the tip of the burner, which is always placed about one inch from an orifice in the furnace through which the spray of oil and air is driven. At the distance of four or five inches from the tip of the burner the oil, when lighted, bursts into a flame,

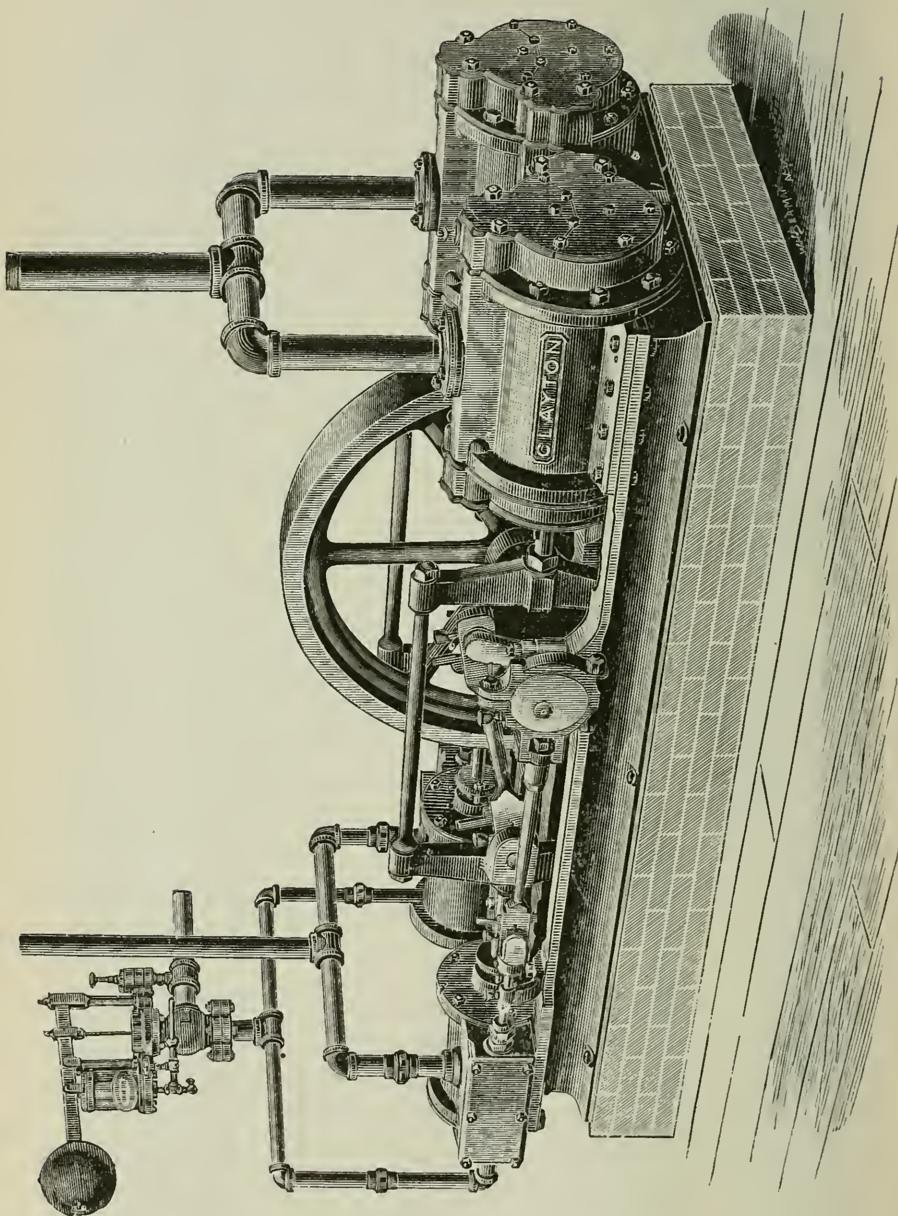


FIG. 2.

which may be varied all the way from a yellow, and if desired, a smoky flame to a clear white flame as bright as an electric light, by governing the proportion of oil and air by means of the cock at the butt of the burner. Its length, also, may be varied from fifteen to sixty inches, or more. The pressure under which the oil is forced into the fire varies all the way from one-half pound to about twenty pounds to the square inch, according as the kind of fire required for the work varies from a gentle heat through different degrees of red heat up to an intense white heat. In this way the Aërated Fuel Company's system meets the first requirement which we have stated, namely, that the fire shall be capable of giving the varying degrees of heat required in each line of work.

Before passing on to notice the other points, we may add, as a further description, that where the system is used on a large scale, it is usually desirable to employ an automatic oil pump and tank (shown in *Fig. 5*, as built specially for this system by the Hall Steam Pump Company), although this is not necessary. From the main storage tank in the ground the oil is raised in small quantity by this steam or belt-actuated oil pump, which is automatically controlled by a float valve in the small tank under the pump. When the oil reaches a certain level in this tank, the pump stops until enough oil has been used by the burners to lower the oil in the tank sufficiently to start the pump again. In practice, the oil pump, in large plants, works continuously, though slowly.

We have already indicated, in general, that the fire is at all times subject to the instant control of the workman by turning the cock at the butt of the burner. This is used where a slight variation only is required. When it is desired to alter the proportion of the air and oil to a greater degree, this is done by partly closing either the air valve in the pipe above the burner or the oil valve in the pipe below. The air pipe is spoken of as being above the burner, but the burner may equally well be placed with its air and oil connections horizontally, and the air pipe be carried down and placed under the floor, as the oil pipe should always be.

In this case the burner is situated at the centre of an inverted ∩.

Our second point, that an oil burner should produce complete combustion leaving neither smoke nor smell, is secured in the Aërated Fuel Company's system, by supplying at the tip of each burner exactly the proportion of oil and air requisite to give perfect combustion. Some free air is also taken in at the opening in the wall of the furnace through which the oil spray enters the box. This opening

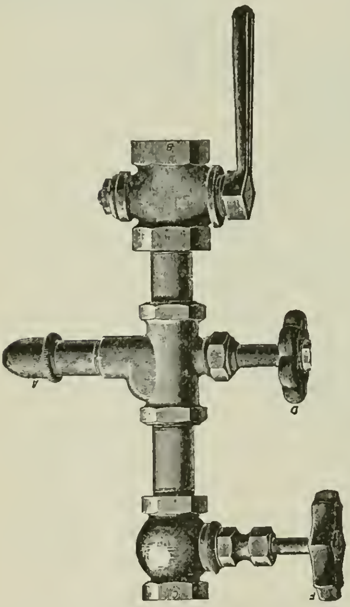


FIG. 3.

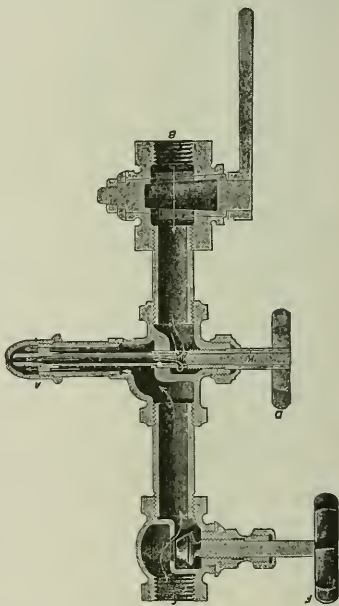


FIG. 4.

varies from one to four inches in diameter. Where the system is used for generating steam, or similar work, requiring a large amount of free air, this is admitted through the ash-pit doors, or better from the rear of the fire box through a special flue under the floor, so that the air passing through this flue becomes heated before it enters the fire box.

A great deal of thought has been expended by the managers of the Aërated Fuel Company, to meet the fifth requirement, namely, to make their system not only as safe

as a coal or wood fire, but even safer, and they feel that they have accomplished this, both from the testimony of the insurance companies and of users of their system, and also from the fact that the system is so arranged that if the air pressure stops at any time from the breaking of a steam or air pipe, the fires are instantly extinguished, and the oil in the pipes runs back to the storage tank. Where an automatic oil pump and tank is used, the oil pump stops as soon

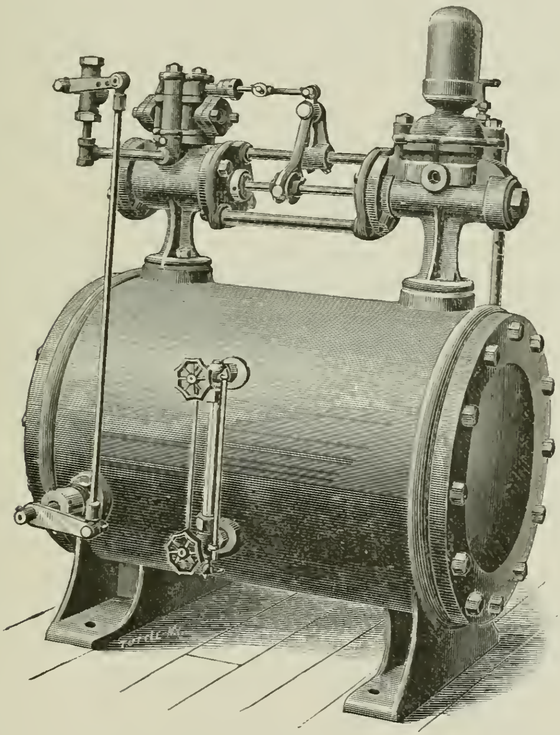


FIG. 5.

as the air pressure stops, because the oil, ceasing to be forced into the fires, rises in the tank under the pump and shuts off the steam from this pump so that only ten or twenty gallons is above ground at any time, and this is stored in the iron tank under the oil pump. The only possible way in which fire can occur with this system, is by some workman carelessly turning on his oil and air and omitting to light the

fire, thus causing a fine vapor of oil to gather in the fire box. If enough of this is allowed to accumulate before it is lighted, an explosion is pretty sure to follow. But all the fires can be instantly extinguished by the engineer, or by any one else, shutting off the steam from the air compressor, and each fire may be shut off by its separate oil and air cocks without affecting any other fire.

A special feature of this company's system is that fires can be obtained at various levels, even extending to different floors of the building, on the same plant, and a different amount of air pressure and a different amount of heat can be maintained at each forge or furnace. In some places furnaces on the same line of piping are using two pounds of air pressure per square inch, and others beside them are using fifteen pounds.

While our first five points are of interest to users of oil as a fuel, a system which should supply them all and yet not comply with our sixth point, namely, to be at least no more expensive than coal is, would not be acceptable to the majority of manufacturers. It should be noted in the first place—and this point is one which it is difficult for many persons to realize—that the amount of oil required to equal a ton of coal varies very greatly in different lines of work. In small forgings, and the melting of lead or other soft metals, the amount of oil needed to equal a ton of coal can be reduced by careful handling to about forty gallons, while where a high degree of heat is required, or where the oil is to be burned in a large fire box, as when used for generating steam, the amount of oil needed to equal a ton of coal rises to 80, 100, 150 and in some cases to 175 gallons. It is difficult to get accurate figures, as most manufacturers either do not know, or will not tell, how much oil they use in their work; but from an abundance of reliable data in the company's possession, from users of the system, the great economy of the system is demonstrated beyond peradventure.

It would naturally be supposed that in order to consume completely varying amounts of oil it would be necessary to increase the number of burners largely according to the

demands of the work, but with the Aërated Fuel Company's system the regulation is so perfect that the amount of oil which can be thrown through the same burner varies through a range of from 1 to 400, perfect combustion being obtainable with whatever amount of oil is used. Of course, a different sized tip is used for various lines of work where the amount of oil needed varies greatly, but otherwise the only object in multiplying burners is to distribute the heat properly through a large forge or furnace.

It is claimed, by the advocates of the various processes for burning oil with steam, that the component gases obtained by superheating and decomposing the steam give additional heat. It is no doubt true that heat is obtained by burning these gases. But the advocates of mixing steam with oil for fuel purposes seem to forget that to decompose the steam, which they throw in with the oil, requires a certain portion of the carbon contained in the oil which is the chief heat-giving factor; so that the extra heat obtained from burning the steam gases is at the expense of part of the heat contained in the oil. In other words, this process amounts to what is called "taking money out of one pocket and putting it into the other." Beside this objection, steam-jet burners require to be fed by gravity and hence are not perfectly safe. A careful test made with one of the best and most largely used of these burners, by the Farr Alpaca Company, of Holyoke, Mass., shows that it takes nearly six per cent. of all the steam made by the boilers to spray the oil to generate this steam, whereas the amount of steam required to run an air compressor for spraying oil by the Aërated Fuel Company's system for this purpose was found to be less than two per cent. of the total amount produced by the boilers. Moreover, the steam so used in spraying oil is consumed, whereas the steam used to run the air compressor may be used to heat the feed-water or be condensed and used again in the boilers. It should be borne in mind also, that where a steam-jet burner is used for generating steam, the fire varies, for the reason that when the supply of steam is ample and its force on the oil strong, the atomizing is more perfectly done and consequently a greater

amount of steam is generated, but when the steam supply is low, a low fire is obtained. In other words, a steam-jet burner works in exactly the reverse way to what is desired, giving most heat when least needed, and least heat when most needed.

To illustrate the amouut of heat which can be obtained, at a recent test in burning terra-cotta at the New York Architectural Terra-Cotta Works, the Aërated Fuel Company's burners, on a circular kiln about eighteen feet in diameter, were lighted at the same time on Tuesday morning as the coal in a smaller kiln, the fire in each case being started at a low degree of heat and gradually increased in intensity to the end of the test. The kiln burned by the Aërated Fuel Company's system was finished Saturday afternoon, or in about 95 hours, while the one burned with coal was not finished until Sunday afternoon, or in about 120 hours. The actual degree of heat obtained here was not taken, but on the fourth day before the highest heat was reached, an iron rod about one inch in diameter thrust into one of the peep holes was melted to the point where the iron ran from the end of it in just two minutes by the watch. A similar test in Springfield, Mass., showed that a three-inch square iron was heated to a dripping heat in twenty minutes when the forge was hot, or in thirty minutes beginning with a cold forge, using not over three-fifths of a gallon of oil. At the Westman Gas Company's regenerative gas furnace, Hackettstown, N. J., two three-sixteenths-inch tip burners gave a heat of 3,200° by a pyrometer test.

In connection with the foregoing, it may be interesting to quote the analysis of lima oil, which is the kind usually used for fuel, made by Prof. Chas. Mayr, of Springfield.

"By ultimate organic analysis, the oil was found to consist of

	Per Cent.
Hydrogen,	17·10
Carbon,	80·20
Oxygen impurities,	2·70
	100·00

"The specific gravity of the oil at 75° is ·831.

"One cubic foot weighs 51 pounds, 14 ounces.

"One gallon weighs 6½ pounds, very nearly.

"Its theoretical heating capacity per pound is 18450·2 (pounds of water × degrees F.) heat units."

The same authority says:

"A weight of 7·3 pounds per gallon would correspond closely to many of the grades of petroleum; also, 20,000 heat units per pound is not an uncommon value for the theoretical number of heat units contained in a pound of the fuel.

"In order to derive approximate formula representing the cost of petroleum and coal, let us make the following assumptions:

42 Gallons oil, ...	1 barrel.
1 Gallon oil weighs	7·3 pounds.
1 Pound coal contains	12,000 heat units.
1 Pound oil contains	20,000 heat units.
Per cent of heat in coal transferable to water, . . .	70 per cent.
Per cent. of heat in oil transferable to water, . . .	80 per cent."

In summing up, it may be said that there are about 200 plants using with this system in this country and in several countries of Europe, and that it is doing about fifty different varieties of work. By fifty varieties we mean that the kind of fire varies to this extent; but speaking generally, it is used for all kinds of iron and steel forging, tempering, welding, annealing, etc.; for making tin-plate; in glass works, for glory holes, lears and ovens; for generating steam; for burning lime, cement, terra-cotta, sewer pipe and brick; for heating chemicals and asphalt; for japanning; for oxidizing lead; for heating retorts in gas works; for drying sand, salt, etc.; for singeing cloth; for shrinking ordnance. From the fact that the system is used in so great a variety of work, there seems to be practically no kind of fire for which it cannot be used, the only question being one of economy as compared with coal; for, as before indicated, while the economy is very great in some lines of work, in other lines there is little or no economy. The line to which the Aërated Fuel Company is at present particularly turning

attention is, for generating steam on steamships and particularly on government torpedo boats. The system is already used on steamships in California, where coal is relatively very expensive, with excellent results; and from the fact that the oil can be stored at the lowest possible point in the ship and forced from that point to the fires, and the fact that the pressure maintained on the oil keeps up a steady flow even when the ship is tossing in the waves, and from the fact that it uses less steam for spraying the oil than any other system, it seems particularly adapted for use on steamships where it is necessary to economize room and steam-power to the greatest extent. If the price of crude oil can be maintained at its present figure, or better if it can be reduced slightly, there is every reason to suppose that before many years the use of oil on steamships, espepially those requiring great speed, and hence great steam generating power, will soon become not unfrequent. It is well known that a well-managed oil fire will get from one-third to one-half more horse-power from a boiler than can be obtained with coal unless a constant force draft is maintained on the coal.

Lack of time has prevented speaking of the improved quality and increased quantity of work produced by the fires of the Aërated Fuel Company's system, but testimony on both these points is ample; so that the system seems destined to be still more widely used in the future, as its merits become more generally understood.

PHYSICAL EXERCISE IN HEALTH AND AS A REMEDY.

BY J. MADISON TAYLOR, M.D.

[*A lecture delivered before the Franklin Institute, December 7, 1891.*]

[*Concluded from p. 240.*]

The intimate connection between the heart and lungs makes it impossible that one of these organs should be disturbed without the other also. One of the first effects of exercise is, of course, to increase the frequency of the heart beat to quicken the blood current. The quickening of this blood current during exercise is the result of two factors. The peripheral circulation is enhanced by the increased demand by the working muscle for blood. The whole vascular system, too, shares in this expedition. Then there is the added need felt by the organism for the aëration of the blood surcharged by the carbonic acid poison; hence there arises an active determination of the blood to the lungs. The central nervous mechanism is depressed, the centres of activity are inhibited and motor impulses are impared. Death may result from all this, but very rarely, because a stop is put to this continued movement by the causes enumerated. Thereupon, a seasonable time being allowed, recovery takes place; these volatile poisons are eliminated and the balance of power comes round again.

Exercise in Childhood and Youth.—The normal states of the infant are feeding and sleeping. There is little further needed during the first year of life but comfortable, clean surroundings and abundant food at suitable intervals, supplemented by ample rest. Plenty of air should be allowed and not much light. The little one should be left alone as much as possible. In certain foundling asylums abroad, the babies are fed and put into well-ventilated, darkened compartments immediately, and under this system they seem to do best. Distinct harm results from over-much attention, and the excitement which comes from fond parents or curious relatives is one of the most hurtful

influences exerted upon early infancy. Absolute freedom should be allowed to the limbs, and yet it is true that certain savage nations keep their infants in rigid dressings until they are able to make attempts at walking, and among such there result exceedingly find physiques. This custom on the part of these savages may reasonably be a hint to us that enforced rest to the limbs is wiser after all. Then, as the child gives distinct evidence of wishing to be more aggressive in its movements, it will probably be high time to encourage it. At any rate, in the second year full freedom might be allowed, and a good plan is to place the infant upon a soft substance on an even surface, like the floor, and encourage all spontaneous movements, and to supply the simplest kinds of toys. Try few educational measures yet.

With the eruption of the first set of teeth, about the end of the second year, a more varied diet is admissible also a wider range of object lessons, though these should be still of the simplest. At the first plain indication of weariness, the child should be encouraged to sleep. As the motor energies become more plainly manifested, so may they be cautiously aided and abetted. In all this be guided by the greatest caution lest unwise interference be hurtful. Take lessons from experience, especially of the natural promptings of the youngster, and beware of all fine-spun theories of childless philosophers and narrow-minded grandparents. As soon as the child makes definite efforts at standing, reaching out for objects, etc., supply it with harmless toys, especially washable ones, which can be kept chemically clean, as of rubber or metal. Let it exercise its senses; its muscular sense, teaching it dimensions of external objects, its eye in judging of distances and colors, etc., as well as the coördination of its limbs. Let it pull things about and put them into its mouth. All animals wish to taste or put objects to their mouths, because the lips are equipped with the most sensitive nerves, and here it can obtain most accurate impressions. The hands have not yet learned nicety of touch, but by handling blocks, etc., soon accuracy comes.

The eye in the child is a perfect organ, and so, indeed, is the digestive tract, with limitations, of course, as to capacity. Not so, however, the limbs and trunk, which have much to learn and large need for exercise. It is best that the objects which immediately surround it should be of uncomplicated shape and color, such as the dawning comprehension may compass and use for comparison as the individual is brought into contact with more complex ones. Bear in mind that the best human animals come from simplest households, as nearly as possible to nature, whose phenomena offer the best object lessons. Civilized comforts and safeguards are not to be despised, but these should not offer elements for confusion. A child is best left much alone. Avoid artificial constraints. When wearied out with the joyous spontaneous movements, which quicken its circulation and expand its lungs, and when feasted with slow contemplation of surrounding objects, it should be able to lie down comfortably and sleep.

By and by the bewilderment of early impressions will be replaced by a growing confidence in the maturing powers and values of surrounding objects. All childhood should be passed in a series of simple object lessons. Some small encouragement is very well, but no distinct teacher of any kind is needed until the motive powers are well established and a fair stock of intelligence has been acquired by its own unaided mental digestion.

When fully able to cruise about the room or garden it may do so, clambering up and tumbling down. So shall it acquire knowledge of its own powers and limitations, so learn to save its own head from injuries and gleefully secure coveted objects. Thus, little by little, stores of information may be acquired, a possession which is all its own, because come at through abundant slow contemplation in its own time and manner and by its own unaided faculties. These powers, too, grow by what they feed on. Selection is thus exercised; eye and hand and leg are brought to the fulness of their strength, and the highest human faculty—judgment —is soon or late acquired. In the mere bodily activities a

healthy child may be trusted to do enough and not too much. If urged beyond its own choosing, the element of excitement comes in, always a confusing factor in measures or results.

Soon the greatest joy will be to play with others of its kind. Impressions from inanimate and other objects will no longer satisfy. Then comes the period of childish games, when running, shouting, rolling about, give tone to muscle and brain. The cerebral part of this partnership, by the way, is largely limited to balancing and the motor functions generally. When, in the course of progress, a certain time comes, by common consent, wherein systematic teaching should be had, then must the bodily powers and parts receive the closest scrutiny. No school system is adequate which does not consider the training of the body as of almost equal consequence with the mind. I venture to assert with small fear of contradiction that no school is fit for your children or for mine which does not supply intelligent medical supervision. Among the more comfortable classes this will be supplied by the family physician, who may have at one time or another sufficiently looked after our boys or girls. When this is not done among those who use the large public schools, a skilled medical supervisor should be provided who shall pass judgment upon every single scholar. Thus will be brought to light heretofore unrecognized weaknesses, and, moreover, a surprising number of deformities; or in the needful repetitions of these examinations hurtful tendencies may be early recognized. In the matter of the eye supervision is becoming pretty generally exercised, and much good already accomplished thereby. Of even more importance, however, is the question of weak hearts, unsymmetrical backs and limbs, narrow chests and twisted pelves. Soon or late calisthenic exercises, military drill, class singing, or some systematic form of body training will be a regular part of the day's instruction in most schools. A steady advancement is being made in the wisdom of educational authorities in all lands. To be sure, we may never attain to that almost perfect system of education pursued by the early Greeks, the products of

which are types of physical and mental beauty which shall serve as models for all time. Then, the pedagogue, the man who walked and talked with his scholars, was equipped with wisdom as well as learning, and capable of intelligently directing the activities of his pupils in body as well as mind. We may hope to have more of this open air object teaching by stream and field, which now is used to supplement the didactic instruction in many large schools and colleges. As parents become more thoroughly aware of the economic needs of educational measures, they will demand as much, or more, of physical care for their children at the hands of the instructors.

Let us turn for a moment to the subject of spinal deformities. This is a typical result of the ordinary school life, when either unduly prolonged or unprovided with proper safeguards in the way of daily supplies of opportunities of exercise. I quote from Dr. J. K. Young, a well-known orthopedist of this city: "The great majority of cases of this curvature originate in children from the age of five or six and upward, and young persons who have been recently in school. This might be thought a mere coincidence, for the school period is necessarily that of development and curvature is a disorder of development. But there is evidence to show that school work and customs are genuine causes, not the sole causes, certainly, but very prominent ones. The origin of latent curvature depends chiefly on two things, weakness of the muscles which support the spine and bad position of the body. Weakness, though not a necessary circumstance, is an extremely common and important one. A bad position constantly maintained will twist the most athletic frame."

Again, Dr. Buckminster Brown, says: "A most pernicious habit, and one which I have very often noticed in school girls, and less often in boys, is that while we are talking to them or during recitations, they stand on one leg. This position is assumed involuntarily, and it is almost always on one and the same leg to which the weight is thrown. The effect of this is easily understood. One side of the pelvis is lifted up, curving the spine on the loins; the opposite leg

is advanced in front of the other, twisting the pelvis and rotating the vertabræ. Of course, the curve of compensation takes place between the shoulders; one is depressed, the shoulder blade gradually projecting, and with the change, and, in fact, assisting to produce it, occurs the spinal twist."

These various warping agents which are inevitable among children confined to the school seats, or to the small variation of standing at their tasks, produce a large amount of actual damage, which remains as seed from which worse trouble grows, or simply impairs constitutional vigor. A large proportion of these are transient effects and overcome by wholesomer living later, hence, never are recognized *per se*. Statistics on the subject are not yet sufficient; a single illustrative instance, however, is significant.

Guillaume, in 1864, examined the schools of Neufchâtel, and found in 350 boys, eighteen per cent. affected with spinal warping, and among 381 girls, forty-one per cent. Careful searching in other schools would give at least analogous results. Now, what is the preventive for this? I quote the uniform opinion of several authorities, who one and all recommend varied muscular activities taken at suitable times as the most important measure. The best are vigorous out-door measures, games, leaping, running, climbing, and all sorts of hard play, the more varied the better.

These should, of course, be not unduly prolonged; especially for girls, it is harmful for them to make large scores at the skipping rope and long match games at tennis or even croquet. Indeed, the best forms of exercise for children are those which speedily shift their consecutiveness and are interspersed with ample periods of rest. In girls there exists an inherent, ofttimes ineradicable indolence, a delight in sacrificing themselves to the proprieties, a misguided sense of decorum which early hinders their right indulgence in active sports. In this their mothers encourage them blindly, even the best of mothers. This early subordinating of their physical impulses leads also to a disregard of the calls of nature, the emptying of the bowels and bladder, and lays the train for life-long discomforts and disturbances.

No one but an active practitioner of medicine can believe how universal is the prevalence of torpid bowels and inactive bladders among the female sex. They seem to revel in the discomforts which arise from the neglect of these most vitally important functions. Again, this inactivity lessens their taste for water, since they rarely sweat. Hence, in unnumbered ways is it important to insist upon much activity among children.

The ordinary sports of boyhood and youth are invaluable. If ample opportunities by stream and field are afforded excellent results follow in healthful and beautiful forms. The tendency is, however, to work along lines of least resistance to specializations and to emphasize already well-marked aptitudes.

This pursuit of out-door sports is necessarily limited to the very few, Dr. Sargent says to probably less than one per cent. of our vigorous young men. Even among the members of athletic organizations only ten per cent. are really active. He goes on to say: "The cause for so little general interest in athletics is due to an increasing tendency with us, as a people, to pursue sport as an end in itself rather than as a means to an end." In making excellence in the achievement the primary object of athletic exercises we rob them of half their value in various ways by (1) increasing the expense of training; (2) by increasing unduly the time devoted to practice; (3) by reducing the number of active competitors; (4) by relying upon natural resources rather than upon cultivated material; (5) by depriving the non-athletic individuals of incentive to physical exertions; (7) by depriving them of their efficiency as a means to health. He points out the fact that the harmonious development of the physique, and the building up and broadening out of the highest types of manhood and womanhood ought to offer inducements enough for which to work.

As to how this may be best accomplished deserves special and constant study—not only for means but incentives. When obvious defects exist judicious, skilled direction is needed in such matters. At Amherst systematic class work obtains good results. In Princeton this was

done in my day by compulsory drill-work with Indian clubs, etc. Military drill has immense value. In the German Turngemeinde all over our country as well as the Fatherland classes from the youngest to the oldest drill in calisthenics regularly, and these are supplemented by out-door work—long walks in vacation time and to a limited degree field sports. The best results come from systematic measures.

For those who need remedial training by movements, the system of Ling is beyond all praise. A host of followers have taken up his suggestions and variously elaborated them and claimed originality for their views, more or less false indeed, but all acting upon his clearly defined principles.

One conclusion stands out clear and distinct from all this inquiry. It may be accepted as almost an axiom that no instance of organic lesion is yet demonstrated to be the direct and sole result of bodily exercises or competitions in one adequately trained.

Rowing.—Dr. John E. Morgan made the first systematic inquiries into the health of rowing men by collecting data from members of the Oxford and Cambridge University Crews down to the year 1872. His data are from 294 men. "The analyses made," he says, "seem to show that if harm really was done by too great strain being laid on the system in early life, that harm may generally be accounted for either by the existence of constitutional unsoundness, or by some deviation from the commonly accepted laws of prudence." Out of these 294 men, 115 considered themselves benefited by their exertions; 162 as in no way injured; 17 were inclined to think, or their friends were, that some injury had been received. Upon careful examination of these 17, 5 had consumption, 3 confined their accusations to the change from extreme activity to a sedentary life, and 5 simply supposed themselves injured, but were alive and in fair health twenty years after. Of the deaths occurring among these 294 men some were from acute illnesses. Calculating the aggregate of years lived up to 1869 by the 294 rowing men, and comparing the expectation of life of these living, according to Dr. Farr's life tables,

he found that the sum of years exceeded the number of years of the expected life tables of the same number of healthy men at the age of twenty. The lives were not shorter, but longer by 2·2 years a man than could have been expected at the time of their first rowing.

Dr. E. H. Bradford, of Boston, succeeded in obtaining, with a fair degree of certainty, the conditions of health of all the members of the Harvard Crews up to the year 1870. He admits his facts possessed less value than those of Dr. Morgan, inasmuch as rowing was then but a recent custom in American colleges. He collected data from 150 men who had participated in the annual University races between Harvard and Yale. Of these 113 were from the classes between the years 1852 and 1870, inclusive. The 37 oarsmen of the classes between the years 1870 and 1876 are rejected, as but a comparatively short time having elapsed since their contest. Of the 113, 13 died in the army and 11 elsewhere. The deaths occurring among these were critically searched for unusual causes, and very few could be directly traced in any way to their competitive exertions. The estimated excess of these actual lives from the insurance tables, over the ordinary expectation, was decided and ample. He points out that it may be urged against this method of reasoning that the oarsmen in these contests are necessarily picked men, and hence the ordinary rates of expected life are calculated for the average man, and hence too low for such instances of marked physical perfection. This objection, however, does not stand against the figures of Dr. Morgan, as he also calculated from insurance tables which only take selected risks. I may say, however, that the physical perfection of these men is practically confined to their demonstrable physical activity, and not judged of from inherited qualities, whereas many times young men fully competent to race would be rejected by careful companies on either their bad family history or personal history of past illness, etc.

Dr. Bradford then goes on carefully to compare the evil effects usually attributed to rowing with the causes of death of the deceased members of the various crews, and

arrives at most just conclusions. These estimated effects, as from rowing, are:

(1) Severe exhaustion after the race.

(2) Disturbance caused by change from the active life of regular rowing to the habits of ordinary life.

(3) Consumption.

(4) Heart disease.

(5) Nervous debility.

It is popularly supposed that profound exhaustion after a race is very common. Newspaper and other sensational reports of races frequently speak of its having occurred. Dr. Morgan could find no instance in the Oxford and Cambridge races so considered by him, nor has Dr. Bradford been able to find any among the Yale and Harvard regattas. He mentions an instance of fainting which was reported as occurring in one of the intercollegiate races at Saratoga Lake, and attributed to a felon on the finger of the sufferer. I know all about this episode, and was myself with the crew that year. The man was my room-mate and had suffered agonies from a felon for days before. He had not slept and scarcely eaten. It was an act of folly on the part of the captain to allow him to row. He was not injured by the race other than locally and temporarily. He lived twelve years after, and died from the effects of diseased appetite, but was a Hercules to the very end. A professional oarsman did die during a sculling race, the exciting causes of which was probably the race.

Exhaustion unattended with remote damage is common in scrub matches, or hastily improvised contests gotten up for fun. Here no suitable preparation has been made by proper training, hence becoming "pumped" or "winded" is inevitable, and practically harmless in healthy young men. I know of one such in which a man fainted in the boat with myself, or immediately after getting out. On regaining consciousness vomiting set in and an indigested meal of huge size stood revealed. This meal was eaten in the protesting presence of the rest of the crew immediately before the race, this individual having arrived late at the rendezvous. He is to-day a vigorous man. A hard race by men

in good condition, of which I have seen many, never produces any obvious distress. It is the part of ordinary prudence for each man to be carefully examined by a competent medical man before undertaking such quest. If he advise against this, let him not race. Even then, however, moderate exercises may safely be followed by him with much advantage.

(2) That a man should sadly miss the delightful buoyancy of feeling which is the possession of the trained athlete, once the exigencies of life demand the putting of his hand to the dull plow of needful toil, goes without saying. Just so the child misses his merry romping days on being forced into the restraints incumbent upon civilized usages. Perhaps the man would be better in morale and physique for a moderate continuance of his muscular activities judiciously mingled with his compulsory bread-winning activities. Indeed, it is often solely his fault if he fails to secure this. So, indeed, is it found best to provide the boy alternate work and play that he may develop best. There need be no sudden precipitous dropping from the river or ball field to the clerical desk. When the ex-athlete gives up suddenly all participation in his old mode of life, it may safely be set down as largely due to choice. The stimulus of a competition removed, one's inherent laziness asserts itself. Hence, doubtless, of one kind or another cause discomforts or worse. The question should not be what harm does this training beget; rather, how much good is wrought for this lazy fellow who for even so brief a space has been kept clean and active. As a matter of fact, healthy men who have become fond of field sports in the most active lines, as time creeps on and their youthful elasticity wanes, take up one and then another of the more passive forms of exercise. Thus small harm can be claimed to result from their whilom exceptional vigor. If it should seem to be so, proof is needed to eliminate such factors as sloth or greed, appetites for food, drink or tobacco. An illustration of the flimsy answers given by those prejudiced against such sports, is the reply of one of the oarsmen who asserted that the changed manner of life after a race brought on, in his case, *an attack of typhoid fever.*

(3) *Consumption.*—There is no competent evidence to prove that this is directly produced or precipitated by rowing contests. A relatively small number of the deaths among these college rowing men was due to this. As I pointed out before, a man capable of doing excellent work in a boat may inherit a tendency to consumption, and this man may yield soon or late to his inherent weakness.

(4) Upon the heart these long sustained physical strains might seem to work most dreaded damage. Dr. Morgan reports three cases of heart disease, and one man with hypertrophied and dilated heart twenty years after his last race. This makes a total of four instances of heart trouble in 294 men, or 13·6 per cent. This is not very far from the average among the records of men in armies.

(5) Nervous debility as a result of racing is not seen, except temporarily.

The Harmful Effects of Physical Exercises.—I have pointed out those discomforts resulting from bodily exertions, and now will give faithfully all I have been able to learn of the permanent danger which comes from these practices. Much exaggeration is indulged in by those who disapprove, and they exhibit some malevolence and small knowledge of the matter. In a careful and long-protracted search from all practicable sources, I have found few instances of organic lesion due to over-exertion. My inquiries were directed to certain physicians, themselves athletes of note, who continued to take interest in the subject; next, directors of large gymnasia, athletic clubs, the *Schriftwarts* of the Turngemeinde, sporting editors and writers on sporting matters, trainers of deserved repute, professional athletes of ripe age and competent to form judgments. Also I put the question directly to college professors who were known to exhibit interest in athletics—here adding to questions of instances of hurt, their views on effect upon the morale of their colleges exerted by athletics.

I made special inquiry also as to the present state of old athletes, professional and other, over fifty years of age—their present bodily state, somewhat over-elaborately, I fear, since I met with small reward. Many cases I have of old

professional acrobats and oarsmen in perfect health over seventy. A fuller study of these will be made and the results given.* I can only now very briefly outline my conclusions, partly because I am trespassing overmuch on your time, and partly because the data has come in very slowly, and requires much revision and further questioning. It may be my privilege to place this matter before you at another time. Suffice now to say the first point to be made is, What was the state of these men before beginning to compete in contests of speed, endurance or strength?

The answers are meagre, but in some cases most suggestive. A gentleman, Mr. R——, prominent as Director of Track Athletics at Princeton for many years, tells me he was a wretched, feeble lad on entering college, and is now, quite ten years later, and after having made some rare records, in sturdy, settled health. This is typical of many answers I get—a feeble youth recognizes grave physical shortcomings, systematically conquers these and finally excels. Several have told me they took systematically to open-air sports to overcome a "tendency to consumption," whatever that may mean. I have known of a few who after years of athletic life finally die of consumption. The number is small and the instances are inconclusive as to causation. I know of a gentleman whose family are closely related to me being told in youth he had heart disease, who, on his own responsibility, went regularly to Wood's gymnasium in New York, and became an all-around athlete whose fame became continental. He died at seventy-three of heart disease, living carefully, but as he chose, and to the very end enjoying vigorous health.

The inquiry into antecedent health, however, promises little. The data obtained is misleading to the last degree. Of greater interest—but beside the present inquiry—is the benefits which can be shown to have accrued from systematic pursuit of athletic sports. This question I am yet working upon—when this be tabulated—if it be in the bounds of possibility, the results will be so large as to com-

* See *Jour. Am. Med. Assoc.*, June 4, 1892.

pletely overshadow the evil effects. One conclusion is uniformly prominent in the instances of damage from boat and other racing. Always the training was either insufficient or bad, or both. For instance, I knew of a man who worked with me daily at Barrett's gymnasium here in Philadelphia years ago, and who then enjoyed a reputation for recklessness in all feats, and but little skill or strength. What he did was wastefully done ever and without any definiteness of aim. He was invited to row in a crew as substitute three days before a race. He did so and collapsed. He is said to have heart disease, what form I know not. He is still alive and a bread-winner for twenty-years.

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

By Emrick A. Werner.

In the following pages I will show how can be found the positions of moving single loads, inducing the maximum and minimum stresses in the members of three-hinged arches or suspension bridges.

The investigations are based upon my "General Theory of Jointed Bow Girders," published in the *Journal of the Franklin Institute*, May to October, 1888, from which I will reproduce here, for the convenience of the reader, in short words, the theorems used in this paper.

Conditions.—Only arches or suspension bridges on two supports without cantilever brackets will be considered.

The arch or suspension bridge shall always have *three-hinged joints or hinges*, one at each abutment—A left, B right and one C in the middle between them. The stiffening structure shall be a *truss*.

Loads.—The bridge may be loaded in any way, with loads of any kind, single or uniformly distributed, at rest or moving, covering parts or the whole of the structure.

Line of thrust is the locus of the points of application of

the thrust *in the span.* The line of thrust is a plane curve of any form, passing through the three hinges $A\ C\ B$. It is independent of the form of the bridge. (See *Fig. 2.*)

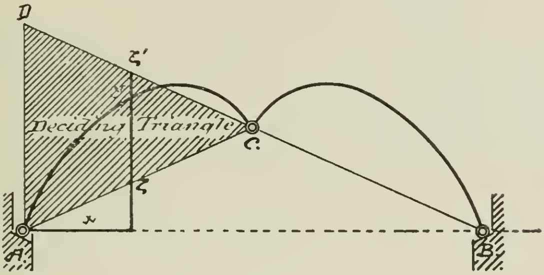


FIG. 1.

Deciding triangle is found in connecting the hinges A and B with C and producing the lines $A\ C$ and $B\ C$ to the intersection D with a vertical at the abutment.

Loads, line of thrust and deciding triangle are variables

EXTERNAL FORCES.

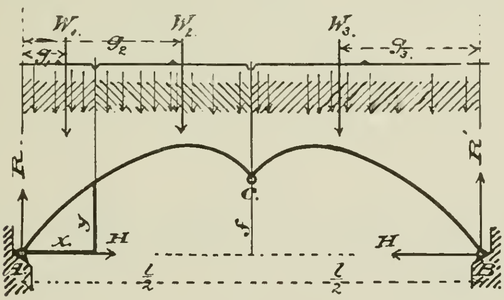


FIG. 2.

$A\ C\ B$ = line of thrust, referred to rectangular coördinates, x, y, the origin lying in A, the x axis passing through B.

$W_1\ W_2\ W_3$ = all the loads from o to x, from x to C and from C to B;

$g_1\ g_2\ g_3$ = abscissæ of the points of application of $W_1\ W_2\ W_3$.—$g_1\ g_2$ positive from the left to the right, g_3 positive from the right to the left:

p = loads taken up in the panel point;

Δx = length of panel;
l = span = distance from A to B;
f = rise = distance of top hinge C above the abutment hinges;
x, ζ', ζ = rectangular coördinates of the two cathedes of the deciding triangle;
$R_1\ R'$ = vertical reactions;
H = horizontal reaction;
M_x = moments in point x.

$$R = \frac{R\,l}{l} = \frac{W_1\,(l - g_1) + W_2\,(l - g_2) + W_3\,g_3}{l}$$

$$R' = \frac{R'\,l}{l} = \frac{W_1\,g_1 + W_2\,g_2 + W_3\,(l - g_3)}{l}$$

$$H\,f = \left(\frac{R\,l}{2} - R_f\right) = \left(\frac{R'\,l}{2} - R'_f\right)$$

$$H = \frac{1}{f}\left(\frac{R\,l}{2} - R_f\right) = \frac{1}{f}\left(\frac{R'\,l}{2} - R'_f\right)$$

$$= \frac{W_1\,g_1 + W_2\,g_2 + W_3\,g_3}{2\,f}$$

$$M_x = \left(R\,l\,\frac{x}{l} - R_x\right) - H\,f.\,\frac{y}{f}$$

$$= \left(R\,l\,\frac{x}{l} - R_x\right) - \left(\frac{R\,l}{2} - R_f\right)\frac{y}{f}$$

$$= \left[R'\,(l - x)\,\frac{x}{(l - x)} - R'\,x\right] - H\,f.\,\frac{y}{f}$$

$$= \left[R'\,(l - x)\,\frac{x}{l - x} - R'\,x\right] - \left(\frac{R'\,l}{2} - R'_f\right)\frac{y}{f}$$

$$= W_1\,g_1\left(1 - \frac{2\,f\,x + l\,y}{2\,f\,l}\right) + W_2\left(x - \frac{2\,f\,x + l\,y}{2\,f\,l}\,g_2\right) +$$

$$+ W_3\,g_3\,\frac{2\,f\,x - l\,y}{2\,f\,l}$$

$$1 - \frac{2\,f\,x + l\,y}{2\,f\,l} = a = \frac{\zeta' - y}{2\,f}$$

$$\frac{2fx + ly}{2fl} = \beta = \frac{\zeta + y}{2f}$$

$$\frac{2fx - ly}{2fl} = c = \frac{\zeta - y}{2f}$$

$$x - \frac{2fx + ly}{2fl} g_2 = b = \left(x - \frac{\zeta + y}{2f} g_2\right)$$

$$M_x = \frac{\zeta' - y}{2f} W_1 g_1 + W_2 \left(x - \frac{\zeta + y}{2f} g_2\right) + W_3 g_3 \frac{\zeta - y}{2f}$$

$$= a\, W_1 g_1 + W_2 (x - \beta g_2) + c\, W_3 g_3$$

$$= a\, W_1 g_1 + b\, W_2 + c\, W_3 g_3$$

Stresses in the Stiffening Truss.—

$$C_x = \left(\frac{M}{h}\right)_x + H$$

$$= \frac{\zeta' - (y \pm h)}{2f} W_1 g_1 + W_2 \left(x - \frac{\zeta + (y \pm h)}{2f}\right) g_2 +$$

$$+ \frac{\zeta - (y \pm h)}{2f} W_3 g_3$$

$$= a\, W_1 g_1 + W_2 (x - \beta g_2) + c\, W_3 g_3$$

$$= a\, W_1 g_1 + b\, W_2 + c\, W_3 g_3$$

or, the horizontal component of the stress in the chord C_x in the point x of the stiffening truss is always equal to the horizontal component of the stress from the moments of the external forces

$$\left(\frac{M}{h}\right)_x$$

in the point x, plus or minus the horizontal component of the thrust H of the external forces.

h = depth of stiffening truss.

$$D_x = C_x - C_{x-\Delta x} = \Delta C_x = \left(\frac{M}{h}\right)_x - \left(\frac{M}{h}\right)_{x-\Delta x}$$

or, the horizontal component of the stress in the diagonal D_x in the panel x of the truss is equal to the difference of the

horizontal components of the stresses in the chord pieces to the right C_x and the left $C_{x-\Delta x}$ of the panel point x.

$$P_x = C_x \; tan \; \mu_{x \;\; \Delta x} - C_{x-\Delta x} \; tan \; \mu_x \pm D_x \; tan \; \alpha_x \pm p$$

$$= C_x \; (tan \; \alpha_x \pm tan \; \mu_{x+\Delta x}) - C_{x-\Delta x} \; (tan \; \alpha_x \pm tan \; \mu_x) \pm p$$

μ, α being the angles of the chord pieces and of the diagonals with the horizontal. p = load taken up in the panel point. or, the stresses in the posts are equal to the sum (algebraically) of the vertical components of the stresses of all the members intersecting in the panel point x.

Stresses in the Cable (Special Strut) and Suspension Rods.—

$$B = H$$

or, the horizontal component of the stress in the cable B is equal to the horizontal stress of the thrust H.

$$E_x = H \; (tan \; \mu_{x+\Delta x} - tan \; \mu_x)$$

or, the vertical stress in the suspension rods E_x in the point x is equal to the difference of the vertical components of the stresses in the cable (special strut) to the right $H \; tan \; \mu_{x+\Delta x}$ and the left $H \; tan \; \mu_x$ of the point x.

All the stresses are sums (algebraically) of stresses from the moments of the external forces. The general equation of any stress is thus:

$$\text{Stress} = a \; W_1 \, g_1 + W_2 \, (k - \beta \, g_2) + c \; W_3 \, g_3$$

$$= a \; W_1 \, g_1 + b \; W_2 + c \; W_3 \, g_3$$

the stresses differing merely in the values of the $a \; b \; c \; \beta$, which are found in adding as directed above the $a \; b \; c \; \beta$ of the chord stresses C making up the stress in question.

$a \; b \; c \; \beta$ can have any value and be positive and negative.

Maximum Line of Stress.—

$$g_m = \frac{k}{\beta}$$

it is found from $b = o$

a, c correspond to dividing lines of the loads, g_m corresponds to the dividing line of the positive and negative increments of $b \; W_2$, hence $(g_m - x)$ is that part of the

truss from x towards the top hinge, which must be loaded to make $b\ W_2$ a *positive maximum.*

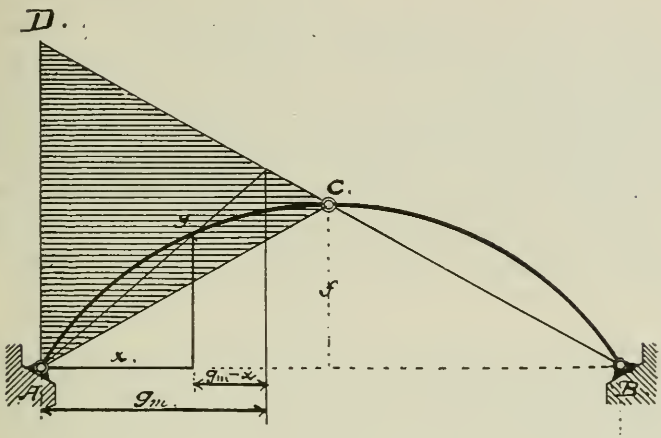


FIG. 3.

Maximum span of the stress are those parts of the truss corresponding to positive $a\ b\ c$, or to $(g_m - x)$ and positive a and c.

Minimum span of the stress are those parts of the truss corresponding to negative $a\ b\ c$ or to

$$\left(\frac{l}{2} - g_m\right)$$

and negative a and c.

Maximum and Minimum Stress.—As $W_1\,g_1$, $W_2\,g_2$, $W_3\,g_3$ do not change their signs, *the maximum of any stress* is found with moving loads, *in loading* those parts of the truss corresponding to positive $a\ b\ c$, or in loading *the maximum span of the stress* in such way, that $W_1\,g_1$, $W_2\,g_2$, $W_3\,g_3$ are maxima.

The minimum of any stress is found with moving loads, *in loading the minimum span of the stress*, or those parts of the truss corresponding to negative $a\ b\ c$, in such way that $W_1\,g_1$, $W_2\,g_2$, $W_3\,g_3$ are maxima.

For members, in which the stress is an explicit function of p = the load taken up in the panel point, that end of the member, taking up no moving load, so as to have p = constant, must be selected in defining the positions of the

moving loads corresponding to the maximum and mininum stress.

These theorems hold good whatever be the form of the bridge, the arrangement of the web members and the kind or way of loading.

For demonstrations I refer to my general theory. See also *The Institution of Civil Engineers*, foreign abstracts, vol. xcv and *Wiener Allgemeine Bauzeitung*, May to October, 1891.

This last publication gives the theory of arches with only positive or negative chord stresses, plus and minus lines, etc.

Maximum and Minimum Stresses from Uniformly Distributed Moving Loads.—With uniformly distributed moving loads we can *a priori* tell the positions of the loads making $W_1 g_1$, $W_2 g_2$, $W_3 g_3$, maxima and have thus the following :

Rule.—To find, with uniformly distributed moving loads, the *maximum stress* in any member of a three-hinged arch or suspension bridge, load fully the *maximum span of the stress.*

To find the *minimum stress*, load fully the *minimum span of the stress.*

For any other kind of loading the positions of the loads making $W_1 g_1$, $W_2 g_2$, $W_3 g_3$, maxima cannot be told beforehand and special investigations must be made in each case.

The definition of the corresponding positions for *maximum and minimum stresses from moving single loads* is the subject of this paper, to which I turn now.

In the general equation

$$\text{Stress} = a\ W_1 g_1 + b\ W_2 + c\ W_3 g_3$$

The variables are:

(1) The loads;

(2) The line of thrust;

(3) The deciding triangle as the rise of the arch; and

(4) The way of loading g.

In our case we need only to know the influence of the

position of the loads g upon the value of the stress. Hence, all the variables with exception of g will be constants, and the equation will be reduced to

$$S = \text{Stress} = \phi\,(g_1\, c)$$

an equation of the first degree, with the stress and the way of loading g as variables. The problem of defining the position of the loads producing the maximum and minimum stress in any member is thus reduced to the problem of finding

$$\frac{d\,s}{d\,c}$$

from an equation of two variables.

To that effect let the bridge be loaded in any way, with moving single loads only, of any value or magnitude.

Let then the whole loading be moved infinitely little, so that no load enters or leaves the bridge, and let the increment

$$\frac{d\,s}{d\,g}$$

be derived.

The stress will then be a maximum or minimum in a dividing line—g being the variable—when the value of

$$\frac{d\,s}{d\,g}$$

goes from positive, through zero, to negative values, or *vice versa, or when*

$$\frac{d\,s}{d\,g}$$

is of different sign to the right and left of the dividing line.

With single loads, this condition can only be verified, *when one of the loads is acting in the dividing line.*

$$\frac{d\,s}{d\,g}$$

will give the conditions of a maximum or a minimum, accordingly as the maximum or minimum span of the stress is loaded.

It remains to give the explicit forms of

$$\frac{d\,s}{d\,g}$$

Increment of the Stresses in the Chords

$$\frac{d\,s}{d\,g} = \frac{d\,C}{d\,g}$$

We have

$$C_x = a\,W_1\,g_1 + W_2\,(x - \beta\,g_2) + c\,W_3\,g_3$$

moving infinitely little, say to the left, it follows

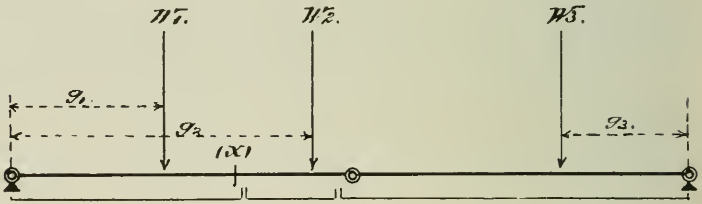


Fig. 4.

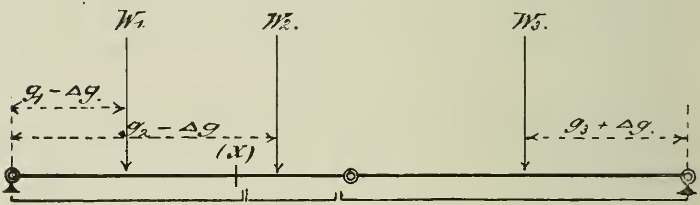


Fig. 5.

$$\begin{array}{l} C_{\Delta x} = a\,W_1\,(g_1 - \Delta g) + W_2\,[x - \beta\,(g_2 - \Delta g)] + c\,W_3\,(g_3 + \Delta g) \\ \underline{\;\;C_x = a\,W_1\,g_1 \qquad\qquad + W_2\,[x - \beta\,g_2] \qquad\qquad + c\,W_3\,g_3\;\;} \\ \qquad\qquad \dfrac{d\,C}{d\,g} = -\,a\,W_1 + \beta\,W_2 + c\,W_3 \end{array}$$

Increment of the Stresses in the Diagonals

$$\frac{d\,s}{d\,g} = \frac{d\,D}{d\,g}$$

As known, the equation $D_x = \Delta\,C_x =$ difference of two

moment stresses, will give only true values, when on the length Δx separating C_x and $C_{x-\Delta x}$ no finite load is acting. Hence, if loads are acting in the length Δx, they must first be transferred according to the law of the lever to the panel points.

It is again

$$D_m = a\, W_1\, g_1 + W_2\, (k - \beta\, g_2) + c\, W_3\, g_3$$

and in calling w the loads acting in the panel x and w_1 and w_2 the parts of w transferred according to the law of lever, to the panel points, this equation gives

Moving infinitely little we have

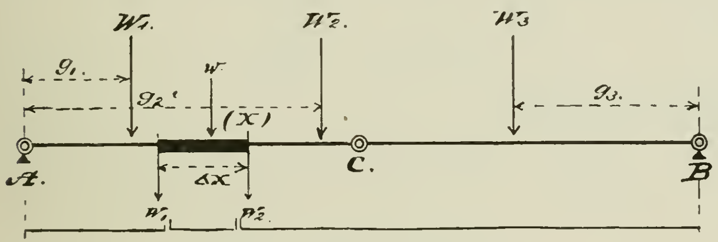


FIG. 6.

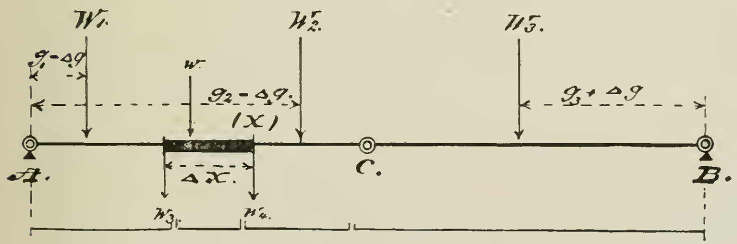


FIG. 7.

From these figures we deduct

$$D_{\Delta x} = W_1\,(g_1 - \Delta g) + W_2\,[k - \beta\,(g_2 - \Delta g)] + c\, W_3 \times \\ \times (g_3 + \Delta g) + a\,(x - \Delta x)\, w_3 + (k - \beta\, x)\, w_4$$

$$D_x = W_1\, g_1 + W_2\,[k - \beta\, g_2] + c\, W_3\, g_3 + a\,(x - \Delta x)\, w_1 + \\ + (k - \beta\, x)\, w_2$$

$$D_{\Delta x} - D_x = [- a\, W_1 + \beta\, W_2 + c\, W_3]\, \Delta g + a\,(x - \Delta x) \times \\ \times (w_3 - w_1) + (k - \beta\, x)\,(w_4 - w_2)$$

But it is

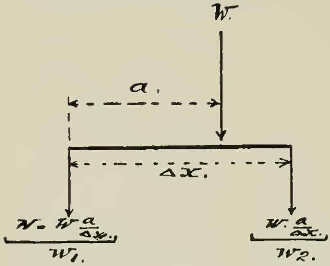


FIG. 8.

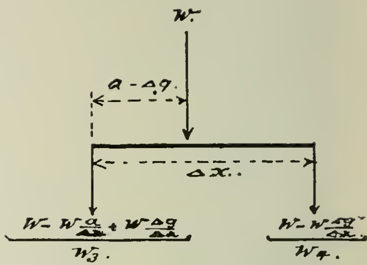


FIG. 9.

whence

$$w_3 - w_1 = + \frac{\Delta g}{\Delta x} w$$

$$w_4 - w_2 = - \frac{\Delta g}{\Delta x} w$$

thence in the limit:

$$\frac{d D}{d g} = - a (W_1 + w) + \beta W_2 + c W_3 +$$

$$+ \frac{w}{\Delta x} [a x - (k - \beta x)]$$

Increment of the Stresses from the Thrust

$$\frac{d s}{d g} = \frac{d H}{d g}$$

$$H = \frac{W_1 g_1 + W_2 g_2 + W_3 g_3}{2 f}$$

or with

$$W_1 + W_2 = W_{\mathrm{I}}$$

$$H = \frac{W_{\mathrm{I}} g_{\mathrm{I}} + W_3 g_3}{2 f}$$

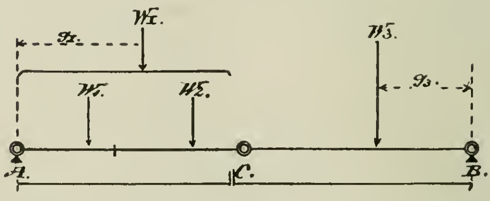


FIG. 10.

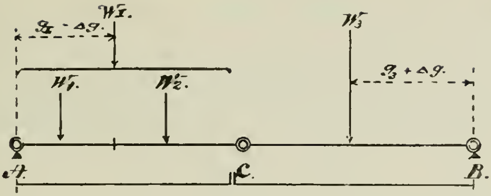


FIG. 11.

moving infinitely little, it follows

$$H_{\Delta x} = [W_1 (g_1 - \Delta g) + W_3 (g_3 + \Delta g)] \frac{1}{2f}$$

$$H_x = [W_1 g_1 + W_3 g_3] \frac{1}{2f}$$

$$\frac{dH}{dg} = - W_1 + W_3$$

and with $W_1 + W_3 = W =$ total load on truss

$$\frac{dH}{dg} = W - 2 W_3$$

Increment of the Stresses in the Posts

$$\frac{ds}{dg} = \frac{dP}{dg}$$

(1) If *one* diagonal is acting at the end of the post, the stress will be

$$P_x = C_x (tan\ a_x \pm tan\ \mu_{x+\Delta x}) - C_{x-\Delta x} (tan\ a_x \pm tan\ \mu_x)$$

or equal to the difference of two moment stresses or to one moment stress, if one C is equal to zero. The maximum or minimum of P_x is thus found as for C or D, as the case may be.

If *one* diagonal, resisting tension and compression, is used in the panel, *one* set of general equations will give the maximum and minimum. If only diagonals *in tension* are used, *two* sets of general equations are necessary, one for each diagonal to find the maxima.

(2) If *two diagonals* are acting together at the end of the post, consider the post as consisting of two coinciding posts *P right* and *P left*, each acted upon by one diagonal.

The stress in the post is then

$$P_x = P \, right \pm P \, left.$$

$$P_x = (C_{x+\Delta x} \, tan \, \mu_{x+\Delta x} - C_x \, tan \, \mu_x) \pm (D_x \, tan \, \alpha_x \pm$$

$$\pm \, D_{x+\Delta x} \, tan \, \alpha_{x+\Delta x})$$

representing the following division of W_1 and W_2.

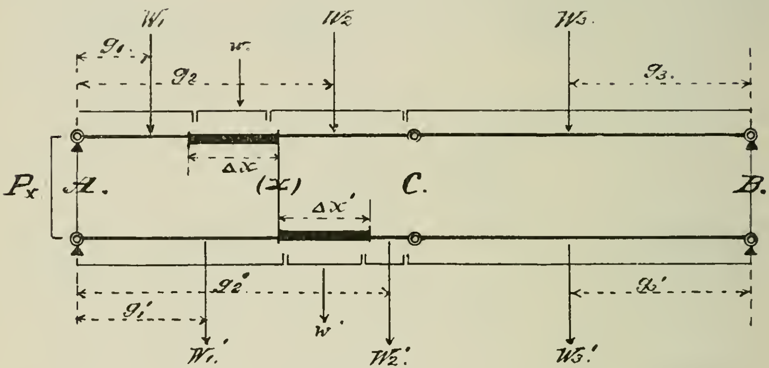


FIG. 12.

As the above equation of P shows, the stress in a post acted upon on one end simultaneously by two diagonals, is a function of the difference of two shearing forces. But for the difference of two shearing forces, *there exists no common dividing line between* W_1 *and* W_2.

Each of the posts *P right* and *P left*, acted upon by *one* diagonal, must thus be treated as a separate post and the results combined. The *maximum span* of the *combined action* of *P right* and *P left* represents thus those parts of the truss corresponding to the *combined positive* $a \; b \; c \; \beta$ of *P right* and *P left*, and the *minimum span* corresponds to the *combined negative* $a \; b \; c \; \beta$ of *P right* and *P left*.

If *two diagonals in tension* act together at the end of the post, the stress can never be greater or smaller than the maximum or minimum stress from *one* diagonal acting at the end of the post, and no special calculations need be made of the stress from two diagonals in tension acting

simultaneously at the end of the post. The demonstration is as follows.

In consequence of the position of the two diagonals in the panels, the stress of one diagonal is always reversed, or the value of *one* D will always be negative.

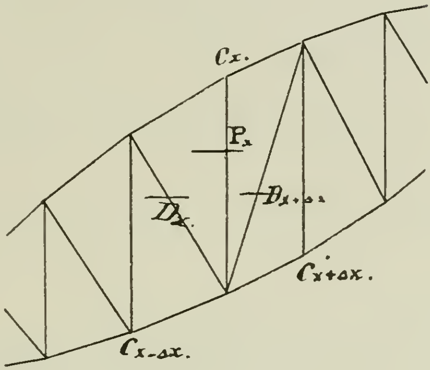


FIG 13

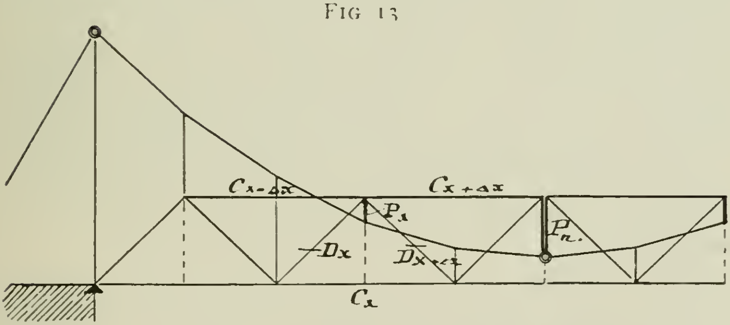


FIG. 14.

The combined action of the two diagonals is thus

$$\pm (D_x \tan \alpha_x - D_{x+\Delta x} \tan \alpha_{x+\Delta x})$$

and P will be

$$\pm P_x = (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) \pm (D_x \tan \alpha_x - \\ - D_{x+\Delta x} \tan \mu_{x+\Delta x})$$

or separating

$$\pm P_x = (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) + (D_x \tan \alpha_x - \\ - D_{x+\Delta x} \tan \alpha_{x+\Delta x}) \qquad (1)$$

$$\pm P_x = (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) + (D_{x+\Delta x} \tan \alpha_{x+\Delta x} - \\ - D_x \tan \alpha_x) \qquad (2)$$

These expressions are maxima or minima, when one of the D, as the case may be, is equal to zero.

Adding and subtracting $C_m \tan \mu_{x+\Delta x}$ in equation (1), writing

$$C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_{x+\Delta x} = D_{x+\Delta x} \tan \mu_{x+\Delta x}$$

and making $D_{x+\Delta x} = o$, we find

$$\pm P_x \; max. = (C_x \tan \mu_{x+\Delta x} - C_{x-\Delta x} \tan \mu_x) + D_x \tan a_x$$

Adding and subtracting $C_x \tan \mu_x$ in equation (2), writing

$$C_x \tan \mu_x - C_{x-\Delta x} \tan \mu_x = D_x \tan \mu_x$$

making $D_x = o$, we find

$$\pm P_x \; max. \; (C_{x+\Delta x} \tan \mu_{x+\Delta x} - C_x \tan \mu_x) + D_{x+\Delta x} \tan a_{x+\Delta x}$$

Both equations of P_x *max.* represent the action of *one* diagonal acting at the end of the post.

But the absolute maximum and minimum stress from one diagonal acting at the end of the post is found as directed, sub. No. 1. Hence the position of the loads making the stresses from two diagonals in tension acting simultaneously at the end of the post must coincide with the positions of the absolute maximum, or else the stress must be smaller than this absolute maximum and need not be investigated separately. The same can be said of the minimum stress.

(3) If *no* diagonal is acting at the end of the post, the horizontal components of the stresses in the two adjacent chord pieces must be the same, or

$$P_x = C_x (\tan \mu_{x+\Delta x} - \tan \mu_x)$$

Hence P_x can never be greater or smaller than the vertical component of C_x maximum or C_x minimum.

Remembering that when no diagonal is acting at one end two diagonals are acting at the other end of the post, we see that the maximum or minimum of P will be found in this case, when

$$C_x \text{ and } (D_x \tan a_x \pm D_{x+\Delta x} \tan a_{x+\Delta x})$$

will be maxima or minima at the same time, as the case may be.

With these expressions of the increment of the different stresses, it will now be easy to formulate the rules deciding the positions of moving single loads, which create the maximum and minimum stress in the members of a three-hinged arch or suspension bridge.

Vertical Reactions R.—Put the heaviest loads on or near the corresponding abutment, so that the total load W and the moment Wg or $W(l-g)$, as the case may be, are maxima at the same time.

The minimum is found with no moving loads at the bridge.

Horizontal Reaction H, or Horizontal Stress B, in the Cable Maximum.—Put a load at the top hinge and load the truss, so that

$$W - 2\,W_3$$

is of different sign, when the load acting at the top hinge is once counted into W_2 and once into W_3.

The Minimum is reached when no moving loads are at the bridge.

Stresses in the Suspension Rods E.—They reach their maximum and minimum with H.

Stresses in the Chords C of the Stiffening Truss.—

Maximum: (1) Calculate in figures.

$$\frac{\zeta' - (y \pm h)}{2\,f} = a \qquad \frac{\zeta + (y \pm h)}{2\,f} = \beta$$

$$\frac{\zeta - (y \pm h)}{2\,f} = c \qquad (x - \beta\,g_2) = C$$

(2) Write the general equation of C.

(3) Make $b = o$ and find the maximum line g_m.

(4) Decide the *maximum span* of C.

(5) Put a load on the dividing line and load the maximum span, so that

$$-\,a\,W_1 + \beta\,W_2 + c\,W_3$$

is of different sign, when the load acting on the dividing line is counted once into W_1 and once into W_2 or once into W_2 and once into W_3, as the case may be.

Minimum: Proceed as above, only use the minimum span.

Stresses in the Diagonals D of the Stiffening Truss.—

Maximum: (1) Substract $a\ b\ c\ \beta$ of $C_{x-\Delta x}$ from $a\ b\ c\ \beta$ of C_x.

(2) Write the general equation of D_x.

(3) Make $b = o$ and find the maximum line of D_x.

(4) Decide the maximum span of D_x.

(5) Put a load on the dividing line and load the maximum span, so that .

$$- a\ (W_1 + w) + \beta\ W_2 + c\ W_3 + \frac{w}{\Delta_x}\left[a_x - (k - \beta_x)\right]$$

is of different sign, when the load acting on the dividing line is counted once into w and once into W_2 or once into W_2 and once into W_3, as the case may be.

Minimum: Proceed as above, only use the minimum span.

Stresses in the Posts P of the Stiffening Truss.—In all instances select that end of the post taking up *no* moving loads for defining the positions of the loads corresponding to *P max.* and *P min.*

Maximum:

(1) *One* diagonal acting at the end of the post.

Proceed as for *D* or *C*, as the case may be.

(2) *Two* diagonals acting at the end of the post.

Consider the post as composed of two coinciding posts, *P right* and *P left*, each acted upon by one diagonal.

Treat *P right* and *P left*, each as a separate post and combine the action of both.

Note.—With two diagonals *in tension* acting at the end of the post, no special calculations are necessary, the corresponding stress being always smaller than the stress from the action of *one* diagonal.

(3) *No* diagonal acting at the end of the post.

Maximum: The value of P_x is always less than

$$C_x\ (tan\ \mu_{x+\Delta x} - tan\ \mu_x)$$

The exact value of P_x is found in making

$$C_x \text{ and } \pm\ [D_x\ tan\ a_x \pm D_{x+\Delta x}\ tan\ a_{x+\Delta x}]$$

a maximum at the same time.

Minimum: Proceed as for the maximum, only use the minimum span or the minimum of the stresses.

A check of these rules can be obtained in the following way:

Any arched truss will become a truss with only vertical reactions, when the horizontal reaction H becomes zero. Hence in making H equal to zero in the above expressions of the arch, these expressions must be reduced to the corresponding expressions of a truss with vertical reactions only. To define the conditions making H equal to zero, we have the equations of M and H.

$$M_x = R\,x - W_1\,(x - g_1) - H\,y$$

$$2\,H\,f = W_1\,g_1 + W_2\,g_2 + W_3\,g_3$$

From these equations follows that y and f must be equal to zero. M becomes then the moment of a truss with vertical reactions only. But we know that these moments can, under no circumstances be equal to zero, between the abutments. Hence the subdivision of W_2 becomes void, and we have as third condition if H shall become zero in the arch, $W_2 = o$, besides $y = o$ and $f = o$.

For a truss, with vertical reactions only the general equations are:

Fig. 15.

$$C_x = \left(\frac{M}{h}\right)_x = \frac{1}{h}\left[\frac{l-x}{l}\;W_1\,g_1 + \frac{x}{l}\,W_3\,g_3\right]$$

$$\frac{d\,C}{d\,g} = \frac{l}{x}\;W_1 - W$$

W = total load

$$D_x = [-\,W_1\,g_1 + W_3\,g_3]\,\frac{1}{h}$$

when h = constant.

$$\frac{d\,D}{d\,g} = W - w\,\frac{l}{\Delta\,x}$$

w = load on panel length $\Delta\,x$.

Introducing $y = o, f = o, W_2 = o$ in the equations of the arch, we find

$$1 - \frac{2fx - ly}{2fl} = \frac{\zeta' - y}{2f} = a = \frac{l - x}{l}$$

$$\beta = o \qquad W_2 = o \qquad b = o$$

$$\frac{2fx - ly}{2fl} = \frac{\zeta - y}{2f} = c = \frac{x}{l}$$

and

$$C_x = a\, W_1 g_1 + b\, W_2 + c\, W_3 g_3$$

$$= \left[\frac{l - x}{l} W_1 g_1 + \frac{x}{l} W_3 g_3\right] \frac{1}{h}$$

$$\frac{dC}{dg} = - a\, W_1 + \beta\, W_2 + c\, W_3$$

$$= - \frac{l - x}{l} W_1 + \frac{x}{l} W_3 = \frac{l}{x} W_1 - W$$

Comparing

$$D_x = a\, W_1 g_1 + W_2 (k - \beta g_2) + c\, W_3 g_3$$

with

$$D_x = [- W_1 g_1 + W_3 g_3] \frac{1}{h}$$

we see that

$$a = - 1$$

$$c = + 1$$

$$(k - \beta x) = c\, (l - x)$$

$(k - \beta x)$ being the coëfficient of the load acting in the point x.

Introducing in

$$\frac{dD}{dg}$$

of the arch

$$\frac{dD}{dg} = - a(W_1 + w) + \beta\, W_2 + c\, W_3 + \frac{w}{\Delta x} [a\, x - (k - \beta x)]$$

it will become

$$\frac{dD}{dg} = + (W_1 + w) + W_3 - w_1 \frac{l}{\Delta x} = W - w \frac{l}{\Delta x}$$

As we see, in the arch, the length of the span, which must be loaded, also the ratio according to which the different parts of this span are to be loaded, to produce a maximum or minimum of any stress, *is variable*, while in the truss with vertical reactions only the length of the span, which is to be loaded and the manner, in which it is loaded in each point, is constant.

Appended are the actual calculations of the stresses, in the members of an upright three-hinged arch and of a three-hinged suspension bridge.

CHICAGO, ILL., February, 1892.

[*To be continued.*]

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, June 28, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 28, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-one members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and lantern slides, which were approved and ordered paid.

Mr. D. A. Partridge exhibited and described a Thomson reflecting electrometer that he had constructed from drawings illustrating a paper on the subject by Sir Wm. Thomson. The instrument was beautifully made, and showed remarkable sensitiveness.

Mr. Paul Winand read the second part of his paper on "Some Points Regarding Multiphase Current." Referred for publication.

Prof. Edwin J. Houston gave "Some Additional Notes on the Graphic Representation of Magnetic Fields." Referred for publication.

Mr. Richard W. Gilpin described a curious changing of polarity met with in a four-pole compound dynamo.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

On POLYPHASED CURRENTS.

By Paul A. N. Winand.

[*A paper before the Electrical Section, at the stated meetings of April and May.*]

Since last year's electrical exhibition at Frankfort, the transmission or distribution of energy by means of polyphased currents, seems to have attracted, to a remarkable degree, the attention of all interested in electrical matters. This system had been proposed and experimented upon for several years previously, but it is only since the successful outcome of the Lauffen transmission that its practical advantages have been generally recognized.

Little has been published as yet in this country concerning its theoretical features, while a number of papers on the subject have appeared in Germany. As the German papers mostly treat the matter in a purely mathematical manner. which is not always favorable to clear insight into the somewhat intricate conditions, I have endeavored to apply to the question a more direct way of reasoning. I fear, however, that I have succeeded but imperfectly in my purpose.

GENERAL CONSIDERATIONS.

The term polyphased or multiphased currents has apparently not yet received a strict definition. It is broad enough to cover any system or combination of connected conductors carrying each an alternating current different in phase from the currents carried by the other conductors. In fact, however, it seems to have been used for designating such systems of alternating currents

> which *can be produced* by means of an armature without commutator. uniformly rotating relatively to a constant field and opposing to the motion a torque which is a constant during the whole of a revolution, or which, by means of stationary and

permanently connected conductors, *can generate* an uniformly rotating, constant field.

The field, in this second case may or may not be provided with iron cores of suitable shape.

The currents and electro-motive forces are generally supposed to follow the simple *sine* law, as usual.

It is possibly by looking at it in this way that the chief promoter of polyphased currents in Germany, Mr. M. von Dolivo-Dobrowolsky, has been led to propose the name of "Drehstrom," or rotary current.

It is evident that in a system of polyphased currents which conforms to the above conditions of possible origin or possible effect, the individual currents and electro-motive forces are not arbitrary, but inter-related as to amplitudes and phases.

One general and characteristic property of a system of currents conforming to this definition can be proved before going into further details.

The rate at which the total energy is generated, transmitted or absorbed in the system is the same at any moment of a period.

This follows directly from the assumption that the torque and the speed are uniform, which means that the rate of consumption of mechanical energy is constant during a period, while the efficiency of conversion is supposed, as usual to be constant during that time and because no energy is momentarily stored up in the armature.* The energy delivered at the terminals is then constant, and it will be so also through the whole system if there is no momentary storing up of energy by reason of capacity effects. Such effects may even be present without disturbing the conditions if properly distributed.

The second alternative of the definition (consisting in simply generating a field) is really equivalent to the first for the case that the torque is $= O$.

* See the paper published since by Mr. C. Steinmetz, in *Electrical World*, of July 16, 1892.

Any system of polyphased currents, however irregularly the phases may be distributed in time and however different the currents may be in magnitude, will thus be governed by this condition of uniform rate of energy together with the general laws of circuits. That the sum of the currents in all conductors of the system which any continuous infinite surface may cut is at any moment = O; and that the difference of potential between any two points on the conductors is at any moment equal to the sum of the electro-motive forces* along any path which may be followed along the conductors to lead from one point to the other.†

We will not dwell any longer on the question taken in its most general form, because in practical applications

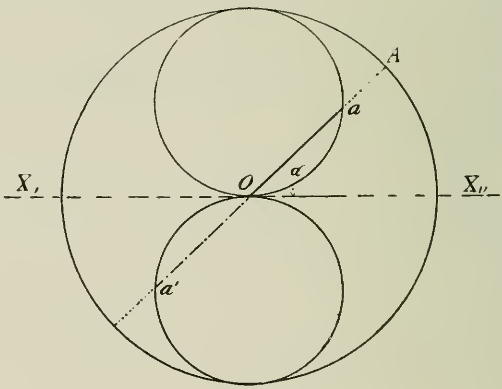


FIG. 1.

polyphased currents are (or, at least, are intended to be) symmetrical; that is, the phases are evenly distributed over the time of one period and the currents are of the same intensity.

SYMMETRICAL SYSTEMS.

The current and electro-motive force in each conductor

---

* These electro-motive forces include $e = i\,R$ taken with the sign of i.

† This is practically equivalent to the law stated by Helmholtz in 1853: That, if in any system of conductors there are electro-motive forces in different parts, the electric tension in any point is equal to the algebraic sum of the tensions which each individual electro-motive force would produce when acting independently of all the others.

are of necessity alternating since there is no periodical commutation of connections. They can be represented as usual by drawing a *sine* curve, and the relations between several of them can be shown by putting the curves along the same axis, but shifted by amounts corresponding to the relative phases.

It is sometimes more convenient to use, as suggested by Prof. Silv. Thompson, the geometrical property which is well known to mechanical engineers by its application in Zeuner's slide-valve diagram.

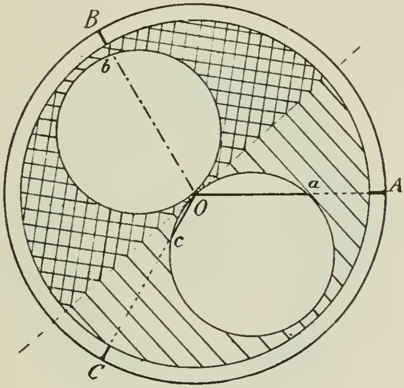


FIG. 2.

Fig. 1 represents this method, which we shall apply later on.

The length Oa, cut off by the small circle on the radius $O\ A$, is proportional to $sin\ a$, being the angle of $O\ A$ with the diameter $X_{\mathrm{I}}\ O\ X_{\mathrm{II}}$. When the radius is below $X_{\mathrm{I}}\ O\ X_{\mathrm{II}}$ $sin\ a$ is negative and this is shown by the part cut off being in the lower circle, like Oa'.

The different length cut off on several radii drawn at angles corresponding to the phases will thus show at a glance the simultaneous values of currents or of electromotive forces in a corresponding polyphased system. If a model be made in which the radii can be rotated together, relatively to the circles, the succession of simultaneous values will appear in a striking manner. It has proved convenient to draw the radii on one sheet and to extend

them to a larger circle, while another sheet, out of which the small circles have been cut, is rotated on top of the first. The two halves of this sheet are made of different appearance, so as to show at once which quantities are positive and which are negative. *Fig. 2* shows this disposition for a three-phase system.

Polyphased generators can be built almost entirely like alternators, and, as for these, it is often convenient to have the armature stationary and the field rotating. Let us con-

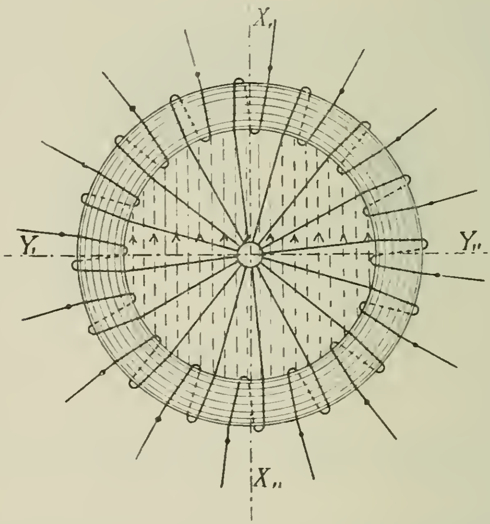


FIG. 3.

sider more closely the simple case of a ring armature with rotating bipolar internal field.

The successive coils of the armature may be connected in two simple ways:

All their right-hand ends may be connected together and their left-hand ones to the terminals of the machine, hence each to one wire of the line, as shown in *Fig. 3*. This has been called the *star* combination. Or the coils may be connected in one series, like a Gramme ring, and the points of junction connected to the terminals (*Fig. 4*), which has been called the *mesh* combination.

We may now trace the distribution of differences of potential and currents at any moment in the conductors.

$X_1\, X_{11}$ is the direction of magnetic axis, $Y_1\, Y_{11}$ a perpendicular to it. Taking each coil separately, the electromotive force e, generated in it is maximum for the coils at $X_1\, X_{11}$ and $= O$ for those at $Y_1\, Y_{11}$, and so are the currents also, if there be no lag, which we will assume for the present.

In the *star* combination the difference of potential E_{1s} between two diametrical terminals is equal to twice the

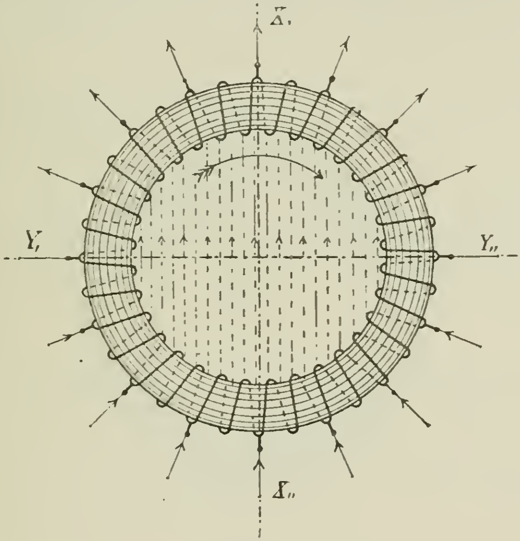


FIG. 4.

electro-motive force e of the opposite coils connected to those terminals, it is

$$E_{1s\,max} = 2e_{max}$$

for the terminals at $X_1\, X_{11}$.

The difference of potential between adjacent terminals is

$$E_{11s} = e_x - e_{x+1}$$

It is equal the difference of the electro-motive forces in the two corresponding coils.

Necessarily

$$E_1 = \Sigma\, E_{11}$$

for half the ring in both the *star* and the *mesh*.

In the *mesh*, however,

$$E_{\mathrm{IIm}} = e$$

so that

$$E_{\mathrm{Im}} = \Sigma e$$

It is interesting to compare the cases where everything is the same (including amount and size of wire), the only difference being in the number of coils (or phases) and in their combination as star or mesh. It is easy to see that in mesh E_{Im} is due to the induction on all the turns of one-half of the ring. The difference of potential between

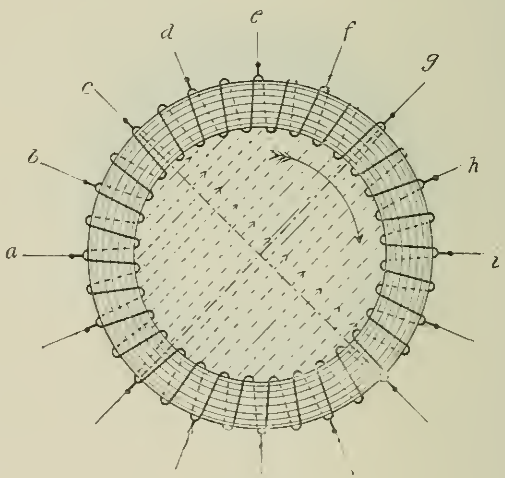


FIG. 5.

opposite terminals is thus independent of the number of coils, but the difference of potential between adjacent terminals, taken at same distance from Y_{I} Y_{II} is inversely proportional to the number of coils because it is proportional to the number of turns per coil.

In star, since $E_{\mathrm{Is}} = 2\,e$ the difference of potential between opposite terminals is inversely proportional to the number of coils, but the difference of potential E_{IIs} between adjacent terminals is, at the same distance from X_{I} X_{II}, nearly inversely proportional to the square of the number of coils.

This is due to the fact that this difference E_{11s} is not only proportional to the number of turns per coil, but also to the distance between the centres of said coils along the ring.

The field $N\ S$ may have any more or less regular shape or distribution and accordingly the electro-motive force in a coil will vary in different ways, as the case may be, with the angular displacement α or with time, as we suppose the motion uniform. For the star the law followed by the difference of potential between opposite terminals is the same as that followed by the electro-motive force in a coil.

For the mesh the law will generally be a different one. As shown above, the difference of potential is, in this case, equal the sum of the electro-motive forces induced in all the coils on one-half of the ring. The difference of potential, between a and i, for instance (*Fig 5*) can therefore, at any time, be considered as equal to electro-motive force in winding from a to h, *plus* electro-motive force induced in coil $h\ i$.

$$a\ i_1 = a\ h + h\ i$$

After the field has moved through an angle equal to the distance of two consecutive coils, the same portion of the field to which was acting on the portion $a\ h$ of the winding, is now acting on the equivalent portion $b\ i$ and the difference of potential at this moment is:

$$a\ i_{11} = b\ i + a\ b$$

The variation,

$$\Delta\ a\ i = a\ i_1 - a\ i_{11}$$

of the difference of potential between the opposite terminals a and i after this angular displacement equal to the space of one coil is thus

$$\Delta\ a\ i = a\ h + h\ i - (b\ i + a\ b)$$

but it is evident that

$$a\ h = b\ i$$

and when the number of coils is large;

$$h\ i = -a\ b,$$

because then coils $a\ b$ and $h\ i$ are practically opposite, if we

only assume that the field, where it meets the armature, is symmetrical around the centre of rotation.

Consequently

$$\Delta a\, i = 2\, h\, i$$

or

$$= 2\, a\, b$$

$$= 2\, c$$

This means that the *variation* of the *difference of potential* between opposite terminals in the *mesh* is equal to the *difference of potential* itself in the *star*, and that, for a large number of coils (or phases), if $E_{1m} = F\alpha$ is the law followed by the *difference of potential* in mesh, the law followed by the same quantity in star is the derivate function

$$E_{1s} = \frac{d\, F\alpha}{d\, \alpha}$$

of the preceding.

Similar considerations would show that the reverse is true for the difference of potential between adjacent terminals..

$$E_{11s} = F\alpha$$

and

$$E_{11m} = \frac{d\, F\alpha}{d\, \alpha}$$

hence

$$E_{11s} = F\alpha$$

and

$$E_{1s} = \frac{d\, F\alpha}{d\, \alpha}$$

and

$$F_{1m} = F\alpha$$

and

$$E_{11m} = \frac{d\, F\alpha}{d\, \alpha}$$

There is only one form of the law for which

$$\frac{d\, F\alpha}{d\, \alpha}$$

is equivalent to $F\, \alpha$ itself; namely, when $F\, \alpha$ is $\sin\, \alpha$ or $\cos\, \alpha$,

which latter is the same as *sin* α, with one-fourth period difference of phase

$$\frac{d\,F\alpha}{d\,\alpha} \text{ is then } + \cos\alpha \text{ or } - \sin\alpha,$$

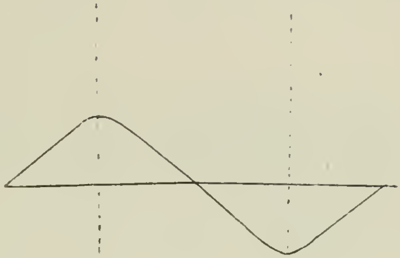
and everything in the system, as well for the star as the mesh combination, follows the *sin* α law as long as the resistances, inductances and capacities can be considered as constants.

I will only remark further concerning this general case, that if $E = F\alpha$, when plotted gives curves of the kinds shown in *Fig. 6.*

$$E = \frac{d\,F\alpha}{d\,\alpha}$$

gives curves like shown in *Fig. 7.*

FIG. 6.



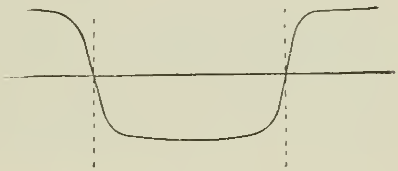
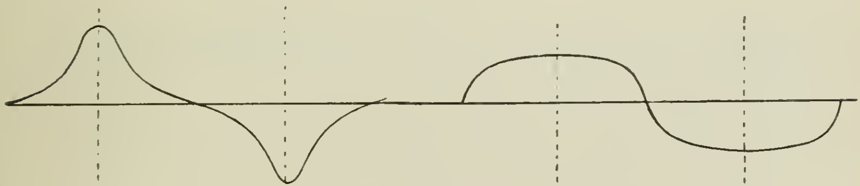


FIG. 7.

It is generally desirable to have the currents and electro-motive forces follow the *sine* law and as this is suffi-

FIG. 6.



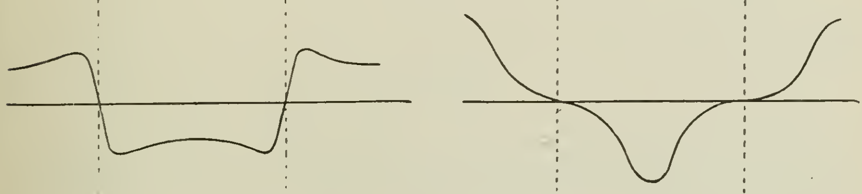


FIG. 7.

ciently approximated in most practical cases, the subsequent considerations will be made under assumption of this law.

Returning then to *Fig. 3* and *Fig. 4* the rule that, for

mesh and star, the difference of potential of opposite and of adjacent conductors follow the laws.

$$Fx, \frac{d\,Fx}{d\,x}$$

and

$$\frac{d\,Fx}{d\,x}, \; Fx$$

which becomes in this case *sin x*, *cox* and *cos x*, — *sin x*, means that in *Fig. 4* the differences of potential are distributed along the terminals and occur in time in the same manner as in *Fig. 3*, excepting that everything is shifted by 90° relatively to the axis of the field.

The electro-motive forces generated in the individual coils are, however, in all respects, the same in both cases.

It means, besides [E_1 being the difference of potential between opposite terminals and E_{11} between adjacent ones], that, as the values of E_{11} along the ring follow the *sine* law, and $E_{1\,\max} = \Sigma\, E_{11}$ in both cases;

$$\Sigma_0^\pi\, E_{11} = E_{1\,\max} = \frac{n}{\pi}\, E_{11\,\max}$$

n being the total number of coils or terminals.

The same relation holds also for the mean differences of potential, or voltages V_1 and V_{11}.

$$V_1 = \frac{n}{\pi}\, V_{11}$$

or

$$\frac{V_1}{V_{11}} = \frac{n}{\pi}$$

This is the relation of the voltages taken between opposite and adjacent terminals, and it is the same for the mesh and the star.

Continuing now the comparison between identical machines, the difference being only in the disposition as star or mesh, we find that the voltages compare as follows:

As the coils contain the same number t of turns in both cases

$$V_{1s} = 2\,a\,t$$

$$V_{1m} = \frac{n\,a\,t}{\pi}$$

a being the voltage per turn hence

$$\frac{V_{1m}}{V_{1s}} = \frac{n}{\pi}$$

in which, V_{1m} and V_{1s} are taken between opposite terminals.

The same relation is, from the preceding, also true for adjacent terminals.

If the armatures are wound so as to give the same voltages

$$V_{1m} = V_{1s},$$

but then the coils contain different numbers of turns t_m and t_s, and the same formulæ give

$$2\,a\,t_s = \frac{n\,a\,t_m}{\pi}$$

or

$$\frac{t_s}{t_m} = \frac{2\,\pi}{n}$$

Considering now the question of currents, we may first assume that they do not lag.

In the star combination they follow then the electromotive force generated in the coils and each line conductor carries the same current, A_s, as the armature winding.

In the mesh, the currents flow out of one-half of the armature into the line conductors and flow back into the other half, as shown in *Fig. 4*.

It appears that, as the current in armature conductors is maximum at Y_1 Y_{11} (this is the case in *Fig. 3* as well as *Fig. 4*) the current is maximum in the line conductors at X_1 X_{11}; that is, at 90° from where it is maximum in the star combination.

The instantaneous value C_1 of the current in armature is equal to the sum of the line currents C_{11} in the conductors

comprised between this point and point X. Consequently its maximum value is equal to the sum of line currents in quadrant $X\ Y$.

$$C_{1\max} = \frac{n}{2\,\pi}\ C_{11\max}$$

and if we call A_{1m} and A_{11m} the mean values of currents in armature and line for the mesh:

$$A_{1m} = \frac{n}{2\,\pi}\ A_{11m}$$

If we compare otherwise identical armatures, the cross sections $S_s\ S_m$ of wires are inversely as the numbers of turns per coil, and as we have found the latter to be

$$\frac{t_s}{t_m} = \frac{n}{2\,\pi}$$

in order to obtain equal voltage

we find
$$\frac{S_s}{S_m} = \frac{2\,\pi}{n}$$

If we consider the machines as equally loaded when the currents are proportional to the cross-sections of conductors, then, for equal load,

$$\frac{A_s}{A_{1m}} = \frac{2\,\pi}{n}$$

This, with the previous equation

$$A_{1m} = \frac{n}{2\,\pi}\ A_{11m}$$

shows that

$$A_s = A_{11m}$$

with which means that otherwise identical machines, one having star the other mesh winding and such number of turns as to give the same voltage, the currents in line, and consequently the energy, will be the same if they are equally loaded.

Considerations almost entirely similar to the above would show that the relations found for the currents and electromotive forces in the armature and line conductors, apply

also to conductors considered as mere resistances, such as lamps.

We have assumed that there was no difference of phase between currents and electro-motive forces. There is generally such a difference, however, but, if everything is symmetrical, the relations between the currents and those between the electro-motive forces remain unchanged, the only difference with the case assumed before being that all what relates to the currents is shifted by an angle equal to the difference of phase relatively to the axis of the field.

It would be more complicated than difficult to show further in a similar manner, that, inversely, the same field can be produced by the same polyphased system with otherwise identical cores and windings, the only difference being in the arrangement as star or mesh.

We have considered more particularly the case of a ring armature. A drum might have been taken as well and would have led to similar results.

It may be interesting to note that the first idea of Mr. Haselwander, one of the pioneers in this line, had been to take two Thomson-Houston arc machines, having armatures of the drum type, and to use one as a dynamo, the other as a motor of a three-phase system. Contact rings would have been substituted to the commutators. He afterwards made use of ring armatures.

THREE-PHASE SYSTEM.

This system has, besides its simplicity, decided practical advantages of its own, These have apparently been first fully recognized and expounded by Mr. von Dolivo-Dobrowolsky, to whose efforts the successful introduction of this system in actual practice is mainly due. We may investigate the relations in this system by means of the diagram or model represented by *Fig. 2*. It shows the star and mesh combination, $O\,A$, $O\,B$, $O\,C$ being the branches of the star, while $A\,B$, $B\,C$ and $C\,A$ are those of the mesh. We have seen above that when the number of phases is large the phases in the star branches differ by nearly 90° from those in the corresponding parts of the mesh.

With as small a number of phases as three, the case is different. The use of the diagram *Fig. 2*, discloses the following facts:

In the moment corresponding to position *I* (*Fig. 8*), the current is maximum and positive in *O A*. Let C_s designate this maximum value.

In *O B* and *O C* the currents are both negative and of same value, by reason of symmetry. They are necessarily

$$= -\frac{C_s}{2}$$

In position *II* (*Fig. 9*), which corresponds to one-twelfth

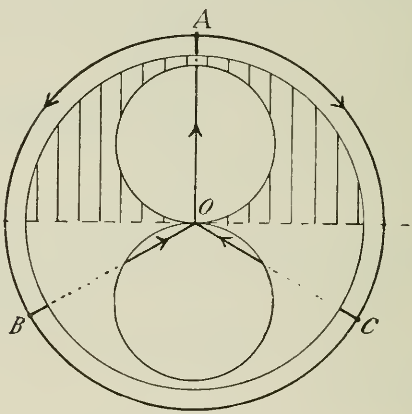


Fig. 8.

period later, or to a displacement of 30° the currents are equal and opposite in *O A* and *O B*.

Their numerical value is

$$\sin 60^\circ\, C_s = \frac{\sqrt{3}}{2}\, C_s = O,866\, C_s$$

At this moment there is no current in *O C*.

In position *III* (*Fig. 10*) [or after another one-twelfth period], the currents are

$$+\frac{C^s}{2}$$

in both *O A* and *O C* and $- C_s$ in *O B*.

The phases and corresponding values of the currents in the branches of the mesh, can be ascertained as follows.

The currents in all conductors are alternating, and since we consider only the case where they follow the *sine* law, we conclude that in position *I*, by reason of symmetry, the current of *O A*, which is $= C_s$, divides itself into two equal parts flowing in opposite directions through *A B* and *A C*,* so that it is

$$-\frac{C_s}{2}$$

in *A B*, and

$$+\frac{C_s}{2}$$

in *A C*, if we consider right-hand rotation as positive.

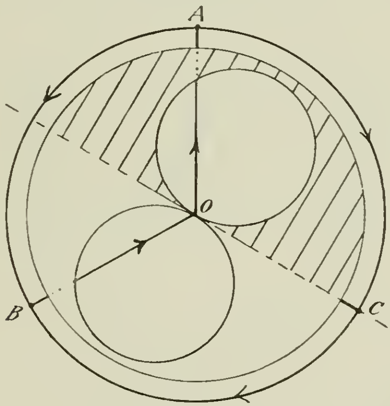


FIG. 9.

There is no current in *B C* at this moment.

As the current in *B C* follows the *sine* law, if it is $= O$ in position *I* it will be maximum one-quarter period or 90° later.

A comparison of *I* and *II* shows that the current is $= O$ in *O C* one-twelfth period or 30° later than in *B C*. This means that the difference of phase between the currents in a branch of the mesh and in the adjacent branch of

* It would carry us too far to show that, to assume that the currents in *A B* and *A C* are not equal, is equivalent to assuming that there is a continuous current in the mesh conductors, and this would be contrary to the definition.

the star situated in the negative direction, is 30° or more shortly; the currents in mesh lead those in star by one-twelfth period.

As to the absolute values of the currents in the branches of the mesh, *III* shows that when the current is maximum and

$$= C_s \text{ in } O\,B$$

it is

$$= \frac{C_s}{2} \text{ in } A\,B$$

but the latter is then at one-sixth period, or 60° from its

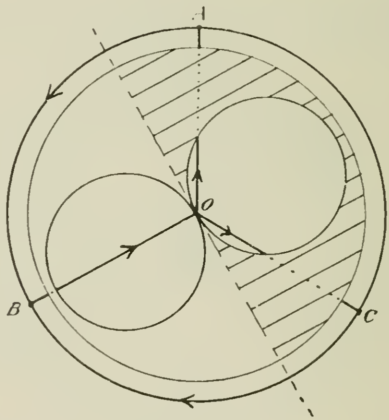


FIG. 10.

zero value. Its maximum value is therefore

$$C_m = \frac{C_s}{2\,sin\,60°}$$

or

$$C_m = \frac{1}{\sqrt{3}} C_s = 0{\cdot}577\ C_s$$

The mean currents in the branches of the star and of the mesh are also in this proportion of 1 to 0·577.

A similar process, applied to the differences of potential, would show that those of the mesh lead those of the star by 30°.

The conservation of energy requires that the watts in the

star be equal to those of the mesh, and also that they be equal in one branch of star and one branch of mesh, since everything is symmetrical.

The voltages are, therefore, in inverse proportion of the currents.

The voltage between O and A, B or C is $\sqrt{3}$ or 1,732 times the voltage between $A\ B$, $B\ C$ or $C\ A$. This result would not be affected if there was a difference of phase between current and difference of potential, because this difference would be the same throughout. The latter appears from the fact that the relations between the currents can be deducted as above, without reference to the electro-motive force or difference of potential, and vice versa the relations between the difference of potential can be found without reference to the currents.

This fact also shows that whatever the resistances, inductances or capacities along the conductors may be, if the currents in the branches of the star (or, which is the same, in the line conductors) form a symmetrical three-phase system, the currents in the branches of the mesh also form a symmetrical three-phase system shifted by one-twelfth period relatively to the former.

It is obvious that in any symmetrical polyphased system, when the number of phases is uneven, by using each current in two opposite ways (for instance, by leading each current through right-handed and left-handed coils), the same effects can be obtained as with a system of double the number of phases Thus a three-phase can be made equivalent to a six-phase and the five-phase to a ten-phase, but the four-phase,* since it is an even number, cannot be doubled in this manner. Moreover, as, for the three-phase, the phases in the mesh are shifted by one-twelfth period, relatively, to those in the star, the phases of the mesh come, by a similar process of doubling, exactly between those of the doubled-star currents, and this is true independently of the resistances, etc.

* Four-phase is often called two-phase, while two-phase is, strictly speaking, nothing but an ordinary alternating current.

This enables to obtain with a three-phase system, having only three line conductors, effects equivalent to those of a twelve-phase. The three-phase supersedes in this respect all others, and especially the four-phase, though the latter can also be operated with three-line wires.

[*To be continued.*]

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Johnson, J. B. *Stadia and Earth Work Tables.* New York: J. Wiley & Sons. 1892. 8vo. $1.25.

Madamet, A. *Tiroirs et Distributeurs de Vapeur.* Paris: Gauthier-Villars. 1892. 12mo. 2 francs 5 c.

Magnier de la Source, L. *Analyse des Vins.* Paris: Gauthier-Villars. 1892. 12mo. 2 francs 5 c.

Möller, M. *Das Räumliche Wirken und Wesen der Elektrizität und des Magnetismus.* Hannover-Linden: Manz und Lange. 1892. 8vo.

BOOK NOTICES.

Annuaire pour l'An 1892, publié par le Bureau des Longitudes. Avec des notices scientifiques. Paris: Gauthier-Villars et fils. 1892. Price, 1.50 francs.

The above-named work, published annually under the direction of the "Bureau des Longitudes," corresponds to the official publication known in this country as the *American Ephemeris and Nautical Almanac.* The present impression is characterized by the introduction of the following new features of scientific interest: A table of stellar parallaxes, prepared by M. Loewy; the most recent elements of the satellites of Saturn, according to Struev; additional data in the tables of comets; two new determinations of the orbital elements of double stars, by Glassenapp; additional data respecting the proper movements of stars, including those of certain stars having a very decided proper movement; an article on the stellar spectra, by Cornu, and a note by the same author on the length of the wave of sound; new data by Moureaux on the phenomena of terrestrial magnetism; in addition to which the volume is closed by the introduction of a number of important scientific notes. W.

Volumetric Tables for Pig Iron, Steel and Ore Analysis. By Edward K. Landis. Pottstown, Pa.: Ledger Job Printing Rooms, Pottstown, Pa. 1892.

This is a small volume of thirty pages, containing factors for calculating from the burette readings, the percentage of

(1) Iron;
(2) Lime;
(3) Manganese, determined by William's method;
(4) Manganese, determined by Volhard's method;
(5) Phosphorus, determined by Emmerton's method.

The especial point of interest in the tables is the fact that they are adapted to a $\frac{n}{10}$ solution of permanganate (or bichromate) that *may not be exactly deci-normal.* Thus, in standardizing the solution, suppose that 1·4 grammes of double iron salt require 35·1 cc. $KMnO_4$ (instead of 35·7 cc., as would be required if exactly $\frac{n}{10}$), by turning to the page headed 35·1, we find at once the factors (from 1 to 9) for each of the above five determinations. The book will be appreciated by all iron chemists. It can be had only from the author (address as above) at a cost of 50 cents. P.

PROGRAMME OF LECTURES FOR THE SEASON 1892–93.

The following course of lectures, to be held during the season 1892–93, has been approved:

1892.

Friday,	Nov. 4.	Prof. Lewis M. Haupt, Civil Engineer, Philadelphia, "Ship Canals" (illustrated).
Monday,	" 7.	Prof. H. C. Bolton, New York, "Alchemy, the Cradle of Chemistry" (illustrated).
Friday,	" 11.	Prof. Lewis M. Haupt, Civil Engineer, Philadelphia, "The Road Movement" (illustrated).
Monday,	" 14.	Mr. John Birkinbine, Mining Engineer, President American Institute Mining Engineers, "From Mine to Furnace" (illustrated).
Friday,	" 18.	Mr. J. C. Trautwine, Jr., Civil Engineer, "Movable Dams."
Monday,	" 21.	Mr. George H. Babcock, President Babcock & Wilcox Company, New York, "The Genesis and Exodus of Steam."
Friday,	" 25.	Mr. Eckley B. Coxe, Drifton, Pa., "The Regulation of Wages."
Monday,	" 28.	Mr. C. John Hexamer, Philadelphia, "Austria" (illustrated).
Friday,	Dec. 2.	Mr. James M. Dodge, Link Belt Engineering Company, Philadelphia, "Rope Power Transmissions."

Monday,	Dec.	5.	Prof. H. W. Wiley, Chemist to the Department of Agriculture, Washington, D. C., "Food Adulteration."
Friday,	"	9.	Judson Daland, M.D., Philadelphia, "A New Method of Separating the White from the Red Blood Corpuscles by means of the 'Hæmatokrit.'"
Monday,	"	12.	Mr. T. Commerford Martin, Editor *Electrical Engineer*, New York, "Electricity in the Modern City" (illustrated).
Friday,	"	16.	Mr. Julius F. Sachse, Editor *American Journal of Photography*, Philadelphia, "Philadelphia's Share in the Development of Photography."
Monday,	"	19.	Mr. George Faunce, Superintendent Pennsylvania Lead Company, Pittsburg, Pa., "Electro-Metallurgy and its Applications to Silver Refining and incidentally to other Metals."
Wednesday,	"	28.	Mr. W. N. Jennings, Philadelphia, "Street Scenes caught with the Kodak."
1893.			
Monday,	Jan.	2.	Mr. Pedro G. Salom, Philadelphia, "The Storage Battery Question."
Friday,	"	6.	Mr. W. H. Jaques, Bethlehem Iron Company, Bethlehem, Pa., "Recent Development of Heavy Ordnance in the United States."
Monday,	"	9.	Mr. Emile Berliner, Washington, D. C., "Technical Notes on the Gramophone, with Illustrations."
Friday,	"	13.	Rev. H. C. Hovey, Middletown, Conn., "Castellated Cliffs and Grand Canyons of Arizona" (illustrated).
Monday,	"	16	Mr. George M. Hopkins, New York, "Optical Illusions" (illustrated).
Friday,	"	20.	Prof. George W. Plympton, New York, "The Engineering Features of Egyptian Temple Architecture."
Monday,	"	23.	Dr. Louis Duncan, Johns Hopkins University, Baltimore, Md., "Electric Power Transmission."
Friday,	"	27.	Prof. H. W. Spangler, University of Pennsylvania, Philadelphia, "Cheap Power."
Monday,	"	30.	Prof. Joseph W. Richards, Lehigh University, Bethlehem, Pa., "The Specific Heats of Metals."
Friday,	Feb.	3.	Mr. Alfred R. Wolff, Mechanical Engineer, New York. (Subject to be announced.)
Monday,	"	6.	Mr. Elmer G. Willyoung, with Queen & Co., Philadelphia, "Electricity and the Ether" (illustrated).
Friday,	"	10.	Prof. Charles F. Himes, Dickinson College, Carlisle, Pa., "Expert Testimony."
Monday,	"	13.	Prof. E. D. Cope, University of Pennsylvania, Philadelphia, "Late Additions to our Knowledge of the Evolution of the Mammalia and Man."

Friday,	Feb. 17.	Thomas C. Clarke, Civil Engineer, New York, "Bridging the Hudson and East Rivers."
Monday,	" 20.	Mr. C. Kirchhoff, Editor of *The Iron Age*, New York, "Copper Mining in the United States" (illustrated).
Friday,	" 24.	Mr. Nikola Tesla, New York, "An Experimental Study of Light Effects produced by Alternating High Potentials" (illustrated).
Monday,	" 27.	Mr. Clayton W. Pike, with Queen & Co., Philadelphia, "How we Measure Electricity" (illustrated).

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 21, 1892.*]

Hall of the Franklin Institute,
Philadelphia, September 21, 1892.

Jos. M. Wilson, President, in the chair.

Present, eighty-six members and eight visitors.

Elections to membership since last report, twenty-four.

Prof. Edwin J. Houston gave a description of his improved methods of fixing and delineating the magnetic field, illustrating the subject by the projection of views of a series of such fields. (See this *Journal*, September, 1892.)

Mr. F. Lynwood Garrison gave an account of some recent trials of Harveyized nickel-steel armor-plate, made by the Bethlehem Iron Company, of Bethlehem, Pa., and tested on the private proving grounds of the company. The results of these trials demonstrated a decided advance in the resisting powers of such plates to the penetration of projectiles. Photographs of these plates taken after the firing test (five shots from an eight-inch gun, powder charge eighty-one and three-fourths pounds, Holtzer projectile weighing 250 pounds). Referring to the last experiment, the speaker stated that the plate (8 x 6 feet x 10½ inches thick and weighing 18,600 pounds), which was a companion piece to one than had lately been tested at the Indian Head proving ground, of which trials a full account appeared in his report published in the *Journal*, had received a total energy of impact of 25,040 foot-tons, fully fifty per cent. greater than the plates were subjected to in the previous trials, and exhibited, nevertheless, much less injury than the plates in the former tests. He considered it doubtful whether armor-plates equal in quality to this had ever been produced elsewhere.

Mr. Louis E. Levy read a paper descriptive of a new process of his invention for producing photo-intaglio engravings, and exhibited specimens of the work, which were greatly admired. The paper elicited considerable discussion and was referred for publication.

Mr. W. N. Jennings exhibited and described several remarkable photographs of lightning which he had obtained during the past summer.

The Secretary described, with the aid of a lantern projection, the Buckman automatic tin-plate machine, and gave an account of its operation at the works of the American Tin-plate Machine and Manufacturing Company, Twentieth and Washington Avenue, Philadelphia. He also exhibited some unusually good specimens of prints in black lines on white ground, made from tracings of line drawings after the general method of making blue prints. These prints were made with a so-called "heliographic" paper prepared by Mr. F. Pontrichet of New York.

The Secretary announced that, with the approval of the Board of Managers, the Committee on Publications was engaged in maturing a plan whereby it is intended that every member of the Institute shall receive the *Journal*, without any increase in the amount of the annual dues. The carrying into effect of this new policy, which, it is believed, will awaken a more general interest in the work of the Institute on the part of its large membership, he explained, was made conditional upon the raising by subscription of a guaranty fund of sufficient amount, to insure that an anticipated deficit in the accounts of the *Journal* during the first few years following the adoption of the new measure, would be amply provided for. The committee, he said in conclusion, entertained no doubt of its ability to obtain the desired guaranty among the members in ample time to introduce the new measure at the beginning of the year 1893.

Mr. Wm. E. Lockwood introduced the following resolution :

WHEREAS, The cities of Chicago and Pittsburg have passed ordinances for the suppression of the smoke nuisance resulting from the use of bituminous coal ; and,

WHEREAS, The Councils of the City of Philadelphia are giving consideration to an ordinance of like character.

Resolved, That the Franklin Institute most heartily endorse such action looking to the suppression of a nuisance which is depreciating property in certain localities in the city.

The resolution was duly seconded and was referred to the special committee charged with the investigation of the subject of the smoke nuisance.

Adjourned. WM. H. WAHL, *Secretary*.

PHOTO-MEZZOTINT

Reproduction of Photograph by Levy's new Photo-Intaglio Process

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A NEW PHOTO-INTAGLIO PROCESS.

BY LOUIS E. LEVY.

[*Read at the stated meeting of the Institute, held September 21, 1892.*]

JOS. M. WILSON, President, in the chair.

MR. LEVY: With the exception, perhaps, of the domain of electricity, there is no other special field wherein the recent advances of science have opened so many avenues of progress and effected such notable changes as in the range of the graphic arts. From the time when, fifty years ago, the earlier researches of Scheele and Seebeck on light-sensitive compounds were first wrought into practical shape by Niepce, Daguerre and Talbot, the applications of photo-chemistry have increased in number and extent to such a degree that to-day the various processes of photographic reproduction would require a long catalogue to merely name them. Many of these variations, though marked, are

unessential; others have proven of scientific interest only, while quite a long list of practical photo-reproductive processes have from time to time been superseded by simpler and more efficient methods.

The new photographic process which I have the pleasure of announcing to the Institute this evening is, as I trust will appear in practice, an effective and greatly simplified method of producing a photographic reproduction in the form of an intaglio engraving. Such engravings, technically known by the French term "photogravure," have been produced for some years past by a variety of photo-chemical processes, the most notable of which are those wherein the result is attained by means of a chrome-gelatin film. The fact that a film of chrome-gelatin becomes insoluble when exposed to light, and remains more or less soluble according to the degree to which light is permitted to act upon it, has been made the basis of a variety of processes for the production of photo-engravings. The gelatin film long served as the most effective means for the production of photo-engravings in relief, and still furnishes the basis for the production of photo-engravings in intaglio. For both purposes the sensitized gelatin film is exposed under a transparent negative or positive, as may be requisite in the subsequent procedure; the unaffected portions and unreduced quantities of the exposed film are either swelled by absorption of a liquid or are dissolved and washed out, and the film then dried. In this condition it may be printed from direct, or it may be used as a mould to produce a reverse in a fusible metal; or it may be covered with an electrolytic surface to receive an electrotype deposit, or it may be moulded in plaster, wax, gutta-percha or other suitable substance, from which, in turn, a reverse can be made by casting or electrotyping. Intaglio photo-engravings have also been produced by a process wherein the varying amounts of reduced silver left in the developed gelatino-bromide plate are made to serve as a corrosive or etching agency on a plate of copper on which the bromide plate is imposed, but in general practice the washed-out gelatin film has thus far proven the most practical means to the desired end.

In all photo-intaglio processes hitherto known or practised, the nature of the plate produced and the end sought to be attained is akin to that which is technically known as a mezzotint or aquatint engraving. The essential feature of such engravings consists of the varying depths to which the design is sunken in the plate, the graduations of depth in the plate corresponding to the gradations of light and shade in the printed impression. The ink being rubbed into the depressions of the design and rubbed off from the surface of the plate, the highest parts of the engraving represent the highest lights of the design, the deepest depressions render the darkest shadows and the intermediate depths produce the half-tone gradations of the picture.

The difficulties attending the production of photogravure plates with the particular degree of graduation of depth which is requisite for an artistic effect in the printed impression are such that the process is practised only by a few, the skill and experience needed for the work being attained only after a long practice and then in a full measure only by such individuals as possess artistic capacity and training. In only one establishment, and that in Paris, has the work been brought to a high degree of quality, and there, as well as in other workshops, the hand of the skilful retoucher is frequently to be credited with the largest share in the final result.

To free this result as far as possible from the limitations of human handiwork, and to bring it forth under the more uniform and definite control of scientific procedure has been my aim in the experiments which have resulted in the present method. This method I have named "Photo-Mezzotint," not because that is the most exact term by which to denote it, but because all the other good names have already been pre-empted and made to do service in other directions.

The essential feature of the new method lies in the fact that the picture, instead of being obtained from a graduated depth of the engraving, is produced from a sunken surface of uniform depth, the gradations of light, half-tone and shade being effected by minute lines and stipples of

varying thicknesses but of uniform distance apart from centre to centre. In this respect the photo-mezzotint may be regarded as a development of the so-called half-tone relief process, the true mezzotint or photogravure effect being attained by reducing the thickness of lines and stipples and multiplying their ratio to the surface to such a degree as to render them invisible to the naked eye. In that way all the finest gradations from pure white to deep black are obtainable, with the result shown by the specimens before us. In these the picture is made up of equidistant stipples, varying from a microscopic point up to a size where they coalesce into a solid black, the half-tones consisting of stipples of about one four-hundredth of an inch in diameter, and about 44,000 to the square inch. If a coarser stipple is used the effect varies from that of a mezzotint and approaches more nearly that of a line engraving, the lights and shades being made up of perceptible lines and stipples, like the effects of a steel or copper-plate engraving of equal texture.

The processes at present in vogue for the production of photo-intaglio plates require not only long experience and a high degree of manipulative skill, but also take up quite a length of time—frequently a week or more—for their completion, and the plate, after passing the stages of the photo-chemical process, has then still to be extensively helped by the work of the retoucher. The retouching of photogravure plates inevitably introduces a degree of uncertainty as to the accuracy of the reproduction, the result as left by the retoucher being frequently very different from the original in its disposition of lights and shades. By this new process all these undesirable factors are eliminated; its manipulations are far more facile, the length of time for the entire work is reduced to a few hours, and the result is complete without the supplementary aid of the skilful engraver, except, possibly, in cases of local blemishes or accidental defects. It is therefore reasonably to be assumed that this new method of intaglio engraving, which has been made the subject of an application for letters-patent, may be regarded as a desirable addition to the category of the graphic arts.

SHIP CANALS.

By Prof. Lewis M. Haupt, Consulting Engineer.

[*A lecture delivered before the Franklin Institute, November 4, 1892.*]

Mr. President, Ladies and Gentlemen:

From Adam to Noah, from Noah to Columbus, from Columbus to Peary, navigation has allured mankind by her charms of adventure and discovery, to thread the labyrinths of continents, and to plough the trackless oceans until the mythical "*Ne Plus Ultra*" of the fifteenth century has become the reality of the nineteenth.

Nor is it surprising that there is so little left to discover when it is remembered that the reward is so great, resulting in the possession, by the discoverer, of the new territory with its hidden resources and boundless wealth.

It does not require any great effort for fleet-footed fancy to span the 400 years which have passed, as a tale that is told, and picture to ourselves a little convoy of three small vessels, manned by a courageous crew of 120 men and their inspired commander,* battling with the waves and currents of the interminable ocean, all to prove the theory that the earth is round, by sailing west to reach the East.

On the twelfth of October, 1492, the theory was verified, and an impetus was given to the Star of Empire which has since outdone Puck himself in girdling the earth.

Transportation has opened the storehouses and granaries of the world and has so knit together the kinship of mankind that famine is allayed, disease abated, poverty relieved, employment furnished, knowledge disseminated, the savage tamed, the heathen civilized, and the race ennobled through its benign influences.

Transportation is the chain which binds together the humanity of the globe. It is composed of distinct yet dependent links, any one of which being broken impairs the

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* Sailed from Palos August 3d, and on October 12, 1492, sighted land.

bond and reduces the efficiency of the whole. The three principal links are waterways, railways and highways. The auxiliary, yet all important adjuncts are the submarine cables and electric conduits, so useful in regulating the operation of the primary conductors. There are many minor sub-divisions, useless to follow in this connection, but it is of importance that a comprehensive view be taken of the relations existing between the three parts of the great system of transportation. There is a prevailing opinion in railroad circles, that the waterways are injurious to their interests, since they can carry freight in bulk at much lower rates, but, paradoxical as it may seem, I believe it is abundantly proven by statistics that such impression is erroneous.* The railway occupies an intermediate position between the water and highway and is dependent upon both for receipts and delivery of a large part of its traffic. But, for this evening, our attention is to be directed to that one phase of the waterway known as the "SHIP CANAL."

The efficiency of any line of communication, whether on land or water, is increased by reducing its resistance and augmenting its tonnage, and this is especially true of waterways, where a short cut of a few miles may often save hundreds or even thousands, as in the case of the Suez and Nicaragua; while the traffic using such channels is a function of their depth and sectional area. It is evident that if the vessel draw more water than that furnished by the canal it is debarred from transit and a large part of the tonnage and revenue is excluded. Hence the great importance of deep draft waterways. In fact their commercial value is estimated to increase *as the cube of the depth*, so that by merely doubling the depth the value is increased eight-fold. Wherever there is a peninsula which separates navigable waters of any magnitude, there will be found an opportunity for reducing the length of a route, and for economizing in transportation. The percentage of distance saved, with the amount and character of the traffic, are the principal factors

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* See in *Engineering Magazine* of March, 1892, a paper entitled, "Do Waterways benefit Railways?"

in determining the expediency of constructing a canal, but there are many subordinate elements entering into the problem.

It should be borne in mind that water, although a public medium, is non-productive of freights, if we except ice and fish, and yet it occupies five-eighths of the globe, hence the distance traversed are relatively large and the rates must be comparatively low. That this requirement is wisely satisfied in the physical world will appear from the following considerations:

Water and air being fluids offer less frictional resistance to bodies passing through or over them than the solid substances in contact in land transportation. Water at rest is also level, having no grades to be overcome, while the undulations of a highway or railroad require every pound of freight to be lifted vertically at great expenditure of power, for which there is no useful return.

Every change of direction on a railroad increases the friction, as well as the distance between terminals, while it reduces the efficiency of the motor, whereas the vessel on an open sea may select the shortest course between ports of clearance and entry. The efficiency of the marine engine is also about seven times greater than that of the locomotive at ordinary freight speeds.

Moreover, the capacity of a vessel is much greater than that of a car or even a train of cars, while its cost per ton of dead load is generally less, and its life is longer. Thus a canal boat of 190 tons would carry as much as seven of our largest freight cars, while an ocean tramp of 3,000 tons would require 110 cars with their engines.

The facilities for loading are frequently greater in the case of ships than of cars, and the time required for an equal volume less. In short, from whatever point a comparison be made, the advantage would seem to be on the side of the water borne commerce. The best criterion, however, will be found in the cost of movement; for example, in 1868 the lake and canal system from Chicago to New York was charging 22·79 cents, as against 42·6 by rail for the same service. Ten years later the water rate had fallen to 9·15 cents as

compared with 17·7 cents by rail. In 1885, the relative rates were 5·87 and 14·0 cents, while in 1891 they were 5·96 and 15·0 respectively, or the water rate was only two-fifths of that by "all rail."

In fact, notwithstanding the great improvements in railway transportation, and the apparent neglect of canals, the latter have been able to maintain their supremacy so far as the cost of movement is concerned ; but the purchase of the canals by hostile management and the systematic solicitation of business by the railroads have seriously crippled the canals without economizing for the benefit of the public.

The cost of carriage by ocean or lake vessels on an open waterway is so low as to be hopelessly beyond railway competition. These rates are but a small fraction of a mill per ton-mile, or about one-twenty-fifth of the lowest rail rates—and explain why it is that the overland tonnage makes a bee line for the nearest deep water channel, and why the proper location for commercial cities is at that point farthest inland which can be reached by ocean vessels. It also serves to show the intimate, reciprocal relations existing between these two great systems of transportation:

"Useless each without the other,"

though they are not often so regarded.

In fact, when this was written, the Trans-Continental Railway Association was in session considering the propriety of a reduction on rates for east-bound freights over the Southern Pacific Railroad, because, as was stated, "the American clipper ships are carrying freight from San Francisco to New York around Cape Horn for $3.50 per ton, while the railroad charges $20, and the ships are getting most of the freight." At least, the railroads appeared to think so! Here is a difference of $16·50 a ton, which it is desired the consumer should pay to maintain a system of transportation which is much more expensive to operate than that provided by nature and without which much of the freight carried at the low rate could not be moved at all. It may be readily assumed that the transcontinental lines do not want the Nicaragua Canal completed, as it would reduce

the distance by sea between San Francisco and New York from 15,600 to 4,900, saving about 10,000 miles, and to Liverpool from 15,600 to 7,600, saving 8,000 miles. Yet this canal would so stimulate the commercial and industrial interests of the United States, both East and West, that I have no doubt the traffic of the transcontinental lines would be largely augmented, in accordance with the observed results of such improvements elsewhere. A fact which is worthy of note. The rate per ton-mile by the clipper ship around the Horn is almost microscopic, viz: $·00225, or about one-fifth of a mill, yet it leaves a fair margin for profit, and the proposition of the Southern Pacific to lower the rate shows either that their present charges are higher than they should be or that it is proposed to carry at or below cost to destroy, if possible, a public benefactor, when the rates will become higher than before.

This is illustrated in the case of the Schuylkill Navigation, which delivered coal forty years ago in this city for prices ranging from seventy to ninety cents per ton for freight. To-day, with the canal under railroad control, the rates for home consumption are more than doubled, and the canal still enters its silent protest, and is disfigured with the decaying evidence of its former greatness.

If there were a profit at seventy cents in former days, when operated by mules, what a handsome revenue could not its lessees secure at $1.80 if operated by the cheaper modern appliances? I believe this canal the most valuable piece of property belonging to the Philadelphia and Reading Railroad Company, if it were only operated to its full capacity.

But to return to the Nicaragua route and its effects on the clipper ships. If it save 10,000 miles each way at ·22 of a mill per ton-mile the total economy would be 64 per cent. and the rate would be only $1. 30 per ton, while as compared with the present rate the sailing vessel could pay $2.20 per ton toll and still more than double its revenue, as it could make more than twice as many trips. This would be equivalent to thirteen mills per ton-mile for toll through

the canal. Steamers could afford a much higher rate as their running expenses are so much greater.

As an illustration of what may be done in the way of reducing the cost of movement on a canal of ordinary dimensions, reference is made to the experience on the Aire and Calder Canal, of Yorkshire, England. It is now carrying steamboat trains of barges composed of ten to twelve boats of about forty tons capacity each. The boats are only 20 feet long, 16 wide and 7½ deep, and the cost of transporting coal on the thirty-five miles of this waterway is only one-sixth of a mill per ton-mile, the boats returning empty. Most of the English canals are of much smaller dimensions, having only 4 to 4½ feet draft. Of the canals in Great Britain, 1,238 miles are owned by the railways, while 1,403 are independent.

The relative expenses by rail and canal there, are as follows:

	Rail. *Per Cent.*	*Canal.* *Per Cent.*
Maintenance of way,	13	0
Maintenance of works,	7	2·3
Repairs of rolling stock,	19	6
Traction,	16	8
Traffic expenses,	30	6
General charges,	15	15
	100	37·3

Showing an economy of 64·7 per cent. by canal. When the railway fever was at its height in England, the general public neglected the canals entirely, but the railway companies bought up all they could obtain and "strangled the whole of the inland water traffic." Now, however, the public, through Parliament, are alive to the advantages of inland water communication, and will not permit any further extension of the power of the railway monopoly over the waterways of the country.*

In this country the air is now full of canals, but the air is not the place for them, they should be on the earth and in operation. Too much time has been lost in considering

* *Consular Reports*, 1890. Evan R. Jones, Consul to Cardiff.

them, while our neighbors over the border, knowing their commercial value, have already spent $54,000,000 in building and enlarging the system bordering the St. Lawrence and the Great Lakes, and in about another year the United States' railway and other interests will awaken to find the enormous lake traffic seeking distant markets through foreign channels, instead of through the shallow 350 miles of canal and 150 miles of partially-improved river, which separate Buffalo from New York. To compete with this system we should have the twenty-foot waterway from the lakes to tide-water, also the ship canals across New Jersey and Delaware to open up our Southern connections; the Lake Erie and Ohio Ship Canal to put us in communication with the rich and populous Ohio River basin, and the Illinois and Michigan Ship Canal to complete the Great Belt waterway to the Mississippi. The Florida and Cape Cod Canals are also important parts of the great system, while the climax is reached in the Nicaragua Canal for the commerce of the world. The economies it would effect are almost inconceivable and do not appear to be appreciated by the public.

There is no need to speculate on the prospective benefits of works of this class when history is replete with illustrations, and yet we are now repeating the experience of the most successful projects in the world. Take the Suez Canal for example, a work which has cost about $100,000,000, and yet pays large dividends. Only fifty-eight per cent. of this amount was expended in the work of construction proper. This project was opposed by the British government officially.

The Prime Minister in 1857 stated his reasons for his opposition. Robert Stephenson, the great English railroad engineer, reported that the canal was impracticable and that he was against it. The sentiment of many other Englishmen as well as of the press was hostile. The *Edinburgh Review* said it was "utterly impracticable" and urged that "the available population or resources of Egypt could not execute such a work in 100 years;" that the cost of maintenance would equal the original outlay; that vessels would

have to be paid to induce them to patronize it, if built; that it might be an interesting question to discuss but could hardly ever benefit mankind.

The *Quarterly Review* followed in the same strain—believing the scheme to be commercially unsound, etc. The effect of this agitation was that while England did not contribute anything to the building, it has since been the largest patron and the greatest beneficiary from its construction.

An English author* in referring to this condition of affairs, recently said:

"No one at that time could have foreseen that in less than thirty years from that date the Suez Canal would have become an accomplished fact, and would have become perhaps the most successful industrial enterprise of modern times; that it would have revolutionized our shipping and transit trade; and that our Indian and Australian possessions would have participated in its advantages to an enormous degree. Prescience of this kind is given to but few men."

Until then no suitable machinery for such work was available, most of the work had been done previously in rude Arab baskets. The total excavation exceeded 100,000,000 cubic yards, yet the work was commenced in 1859 (April 25th), and opened to commerce November 17, 1869, or in ten and a half years.

The company was incorporated December, 1858, with a capital of $40,000,000, divided into 400,000 shares, @ five per cent. interest to be paid during construction.

Of this capital England subsequently bought 176,000 shares, @ 113, recently quoted at $550, and on which twenty-three per cent. dividends have been paid.

The traffic on this canal has exceeded the most sanguine expectations, and the receipts for 1890 were $13,485,000.

In 1886, electric lights enabled the canal to be used by night as well as by day, and the traffic increased rapidly in consequence, while the average time of transit has been

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* J. Stephen Jeans, *Waterways and Water Transport*, London, 1892.

reduced from thirty-three hours fifty-eight minutes to twenty-two hours nine minutes. The number of vessels passing through in 1890 was 3,389, carrying a net tonnage of 6,890,014 tons. Hence the average tonnage was 2,033 per vessel, the average charge $3,976. The distances and the tolls were fixed in the concessions at ten francs ($2) per "ton capacity" (an expression which gave rise to subsequent difficulties), and ten francs for each passenger. But these rates are prohibitory for the lower class freights, and hence more than forty per cent. of the Eastern trade is still carried around the Capes. In 1885, the rates were reduced to $1.85 per ton.

The trunk of this canal, 99·9 miles long, is only 72 feet wide at bottom, 196 at top, and 26¼ feet deep, but the traffic has increased to such an extent as to justify its enlargement.

This single instance might suffice to point the moral, but general deductions cannot be drawn from special cases, hence I beg to call attention to a still more remarkable instance of the development of our national resources, due to increased transportation facilities, as illustrated in the SAULT STE. MARIE Canal, at the outlet to Lake Superior, which during the 226 days of navigation in 1890 carried 8,454,435 tons, at a cost per ton-mile of 1·3 mills.

Of this only four per cent. was carried in Canadian vessels, yet Canada is rapidly pushing a rival and larger canal to completion around the falls.

The "Soo" Canal, as originally built in 1856, cost $999,802.46. It was enlarged by the United States between 1870 and 1883 so that the lock might be 515 feet long, 80 wide and 18 deep at a cost of $2,171,000, and a second enlargement is now under contract which is estimated to cost $4,738,865, to result in a lock 800 feet long, 100 wide and 21 deep. The canal is only about one mile long and was transferred to the General Government, by Michigan, in 1881. The cost of operation and maintenance in 1890 was only $45,417.66.

Thus in the past decade the traffic of Lake Superior alone has outgrown the capacity of a lock, which, when it was built, was supposed to be adequate to meet all require-

ments for many years. It is therefore a very moderate estimate which places the traffic through the Nicaragua Canal at 9,000,000 tons. Upon this basis, and the reasonable average charge of $2.50 for the 169 miles, the revenue would be $22,500,000, or twenty-two and a half per cent. on the capital, while the canal would tap the commerce of the world.

There are so many ship canals in process of construction throughout the world that even to repeat their names and dimensions would become burdensome, but a few of these are deserving of mention for the sake of the argument and lesson which they impress. Among them may be mentioned the NORTH SEA AND BALTIC CANAL intended to connect the waters named in the title, whereby 237 knots will be saved, thus shortening the journey of sailing vessels by at least three days, and of steamers by about twenty-two hours, in normal weather. The tolls for this saving are fixed at the low rate of eighteen cents per registered ton. This channel will be 61 miles long, 85 feet wide at bottom, 196 at top, and 28 feet deep. There will be only two tidal locks. The heaviest cut is 98½ feet deep. The contract price in 1889 was twenty cents per cubic metre, but the machinery was not being worked to advantage as the ladder dredges then used were idle, while the cars were run off to the dump. In this case the length of the canal is about twenty-seven per cent. of the distance saved.

The AMSTERDAM SHIP CANAL is another illustration of a great canal constructed to reduce the distance to the sea, for although the North Holland Canal, eighteen and a half feet deep, furnished an outlet, yet the competition with Antwerp and Rotterdam was so severe that it became necessary to reduce the distance and increase the draft to accommodate the larger vessels coming into use. By this new line the distance was reduced from fifty-two to fifteen and a half miles, which is forty-two per cent. of the distance saved. The difficulties to be overcome by this canal were unusually great, but they have been surmounted, at a cost of $15,000,000, or about $1,000,000 per mile. This channel is eighty-eight and a half feet wide at bottom, and only twenty-three feet deep.

But time will not admit of an extension of this description of the many completed and successful ship canals to be found. These few have been cited as a basis of comparison for a projected work which I shall now describe and which presents exceptional facilities for construction and traffic. It is believed to be unrivalled in the results to be attained in proportion to the amount required to secure them. I refer to the short link known as the Chesapeake and Delaware Canal, which unites these great bays with their tributary territory, reaching almost to the Rocky Mountains.

The peninsula separating the "Mother of Waters" from the Delaware extends southwardly 175 miles from the narrow neck of land which the canal traverses, while the distance across is but thirteen and five-eighths miles. Prior to the railroad era, the importance of piercing this barrier and thus saving over 300 miles in the journey from Philadelphia to Baltimore by water was fully realized, and although the resources of the country were very limited, the population small and scattered, the facilities for construction very meagre and the work to be done great, our public-spirited ancestors were not deterred from undertaking it.

The canal company was incorporated by the Maryland Legislature in 1799, and work was begun in 1804, but little progress was made until after the completion of the Erie Canal in 1825, when Judge Benjamin Wright, who built a large part of this work, was appointed consulting engineer, and pushed the project so vigorously, that in September, 1829, barges were allowed to pass regularly through, and on October 17th it was officially opened with imposing ceremonies.

The magnitude of this undertaking at so early a date can scarcely be appreciated at this stage of applied science. In the "Deep Cut," which is nearly four miles in length and seventy-six feet deep at its highest point, there were 3,500,000 cubic yards of earth, which were removed and deposited beyond the sides of the cut, making the present height in some places 100 feet. There were difficulties from landslides and bottomless marshes, so that the excavation and fill

exceeded the original amount by over ten per cent., yet the entire work was rapidly completed at a cost of $2,250,000, or $161,000 per mile.

The general dimensions of the trunk of this original canal were the same as those of to-day, viz: 66 feet wide at the surface, 36 feet at the bottom, and 10 feet deep, while the locks were 100 feet long and 22 feet wide, but in 1854, or a quarter century later, they were enlarged to 220 feet in length by 24 feet in width, which dimensions they still retain, although much too small for the vessels of to-day.

There are two levels to surmount; the first extending from Delaware City, where there is a tidal lock of six feet lift, to St. George's, four and a half miles; the second reaches from St. George's lock, with its ten feet lift, to Chesapeake City, about nine miles. Here there is a single lock of sixteen feet descent into Back Creek, a tributary of Elk River, which in turn debouches into the bay.

The route passes through a rich agricultural country, and the channel is far from being a contracted ditch, such as the name canal generally suggests. With the exception of the pass through the defile of the Deep Cut, it is a succession of pools and broad streams, varying in width from a few hundred feet to nearly a quarter of a mile, and for a large part of the distance the tow-path does not conform to the sinuous banks, but winds gracefully along an embankment placed in mid-stream. These features are mentioned because they are peculiar to this line, and form exceptionally favorable conditions in the project of enlargement.

For sixty-three years this waterway has continued to perform a valuable service, but in the race for supremacy, and the expansion which has taken place in the capacity of vessels, it has gradually fallen to the rear, until now it may be said to be antiquated and unable to fulfill the purpose of its builders.

In 1871 a National Commercial Convention, assembled in Baltimore, memorialized Congress to make an examination for a ship canal across the peninsula, and in consequence surveys were made of eight different routes, with estimates for their construction ranging from over $41,000,000 to $7,-

605,471. This last was for the Chesapeake and Delaware route, with approaches extending all the way from Baltimore to the sea, and providing a channel twenty-seven feet deep, measured from mean low water, having 100 feet width at the bottom.

In making his report on this project, Col. Wm. P. Craighill, in referring to the present canal, said: " But this has neither depth nor width enough for the accommodation of steamers or sailing vessels designed to cross the Atlantic," and in speaking of its strategic value he observed: "It will be doubted by no one that a deep-water connection between the two bays would be of vast importance in the contingency of a war with a maritime nation;" also, "It may be assumed that if a war with one of the great naval powers should arise, and the mere appropriation of the money could provide such a channel of communication between the bays, the amount would be at once provided without hesitation. That would, however, be too late." For security of communication and defense this route is superior to any other. Thus its importance to the Government from a military point of view is conceded, while its value to the commerce of the seaboard cities, as well as the great West, is also manifest by the great economy which would result to transportation from such enlargement. The saving each way of 190 miles for foreign commerce and 330 miles for the coastwise, by a canal only fourteen miles in length, becomes a necessity on the part of the Government and of the owners of the channel, if it is desired to render our naval armament doubly effective, and to maintain and stimulate our commercial development.

But in every engineering enterprise it is important "to sit down first and count the cost," as well as the revenue.

This has been done on the part of the Government and as already stated it was estimated at over $7,000,000, but of this amount $3,249,663.56 was for dredging in the approaches, and $4,355,807.80 was for the canal, 100 feet wide, and its locks, bridges and other works, including land damages. These dimensions are, however, unnecessarily wide for the present, especially in view of the short length

of the deep cut. There is no need of a double track through these four miles and hence a smaller section would prove just as effective and much cheaper. The Suez Canal is but seventy-two feet wide at bottom, and the Amsterdam eighty-six, while the Sault, which to-day outranks in tonnage any canal in the world, was only 64 feet wide and 13 feet deep up to the date of its enlargement, which was completed in 1882. The present dimensions are 108 feet wide at the narrowest part, increasing to 500 just above the lock, and 16 feet deep, the section being rectangular.

In 1840, only fifty-two years ago, when the Senator from Michigan proposed to have the Government build the "Soo" Canal, Henry Clay opposed it because, as he said, it was "*A work beyond the remotest settlement in the United States, if not in the moon.*"

On August 26, 1852, the Government granted 750,000 acres of public lands to the State of Michigan as a subsidy for this canal, which was constructed by a private company and turned over to the State in 1856. In 1869, the State provided for the future transfer of this property to the Government, and it has proven to be one of the best investments the country has ever made.

But to return to the question of width. As intimated, by a reduction of width to a limit sufficient to pass the largest ocean-going vessels in single file, the cost of construction may be kept within $3,000,000 for the fourteen-mile canal, while the revenue would be derived from the entire foreign commerce of Baltimore going to Northern and Eastern ports, which is ninety per cent. of the total, and a large local and coastwise tonnage, all of which aggregate for the two bays, 27,000,000 tons. Of this amount twenty per cent. would no doubt traverse the canal. This at the low rate of fifteen cents per ton would produce a revenue of $810,000. After deducting expenses it should leave not less than fifteen per cent. for dividends and interest on the capital.

As the economic value of a waterway is dependent upon the ratio of its length (and hence its cost) to the distance saved, it will be seen by comparison that there are only two

canals in the world which surpass this one in this particular—they are the Suez and the proposed Nicaragua. The Suez canal, 100 miles long, saves 3,750 miles. Its length is therefore nearly three per cent. of the distance saved. The Nicaragua, 169 miles long, is less than two per cent. of the 10,000 miles which it would save.

The Chesapeake and Delaware is but four per cent. of its greatest saving.

The North Sea and Baltic, sixty-one miles long, is twenty-seven per cent. of distance saved.

The length of the Florida Ship Canal would equal twenty-nine per cent. of the distance cut off, but as it would be 169 miles long and transit through it would be slow, the economy in time would be only twelve hours between New York and New Orleans.

The length of the Amsterdam Canal is forty-two per cent. of the former route.

In short, it would seem that there are but few, if any, places on the face of the globe where so small an expenditure of capital gives promise of such large and immediate returns, where there is so large a commerce in sight in the adjacent and tributary waters, where the benefits to the overland lines of transportation will be so great and where the work will be of the utmost practical utility to the Government in increasing the efficiency of its naval force in time of war, and a potent factor in removing cause for war with any foreign power in times of peace.

In fact its construction becomes a matter of necessity if we hope to keep pace with and aid in the symmetrical development of the commercial interests of our country as a whole.

The lecture was closed with a number of views taken along the line of the Chesapeake and Delaware Canal, illustrating the capacity of the waterway for enlargement and the most improved form of machinery available for construction.

STUDIES ON THE STRATIFICATION OF THE NORTHERN ANTHRACITE FIELD OF PENNSYLVANIA.

BY HENRY A. WASMUTH, M. E.

The Susquehanna River at one time crossed the nearly horizontal anthracite measures, until the whole strata precipitated, either by the shrinkage of the earth's crust, or by volcanic influences, or by both, resulting in the origin of the present long and narrow synclinal of the northern anthracite field. This theory is proven beyond doubt by the washout of the Baltimore coal seam of Forty Fort Colliery, demonstrated in *Figs. 1* and *2* of accompanying plate.

Simultaneously with the precipitation of the strata, the basin, curbed by conglomerate, became filled with water, sand, pebbles and sulphuric clay by the river until leveled up, the water found an outlet towards north near Nanticoke, most probably by the Harvey's Creek bed, then running towards Shickshinny Creek and finally about Mocanaqua across the anthracite measures towards the south.

Since that time, most probably at the beginning of the cretaceous period, erosion went on steadily, the Susquehanna River eroded deeper and deeper the curb of conglomerate at its inlet and outlet, deposited and re-deposited the debris thus produced or carried on, until the present condition of the Wyoming Valley was brought about.

The greater part of the carboniferous formation, with its synclinals and anticlinals of England, Belgium and Westphalia is overlaid by enormous layers of the cretaceous formation.

The lignite deposits of the cretaceous period of Central Russia (Ryasan government) and of Bohemia have a roof of sulphuric clay from a few feet to 400 feet thick, partially overlaid by quicksand in Russia and by gravel from the mountain streams in Bohemia. The sulphuric clay of the buried valley near Forty Fort Colliery is similar to the clay

of the lignite deposits referred to, and therefore the conclusion is justified that the clay of the buried Wyoming Valley is of the cretaceous period, and that the disturbances of the horizontal anthracite measures are assignable to the cretaceous period.

Assuming that at Forty Fort Colliery the distance from outcrop to outcrop of the Buck Mountain coal seam is 27,000 feet, and the depth of its synclinal 900 feet, then the breadth of the horizontal coal seam of the present synclinal would be about 27,100 feet, or in other words, at the time of the precipitation of the strata, its horizontal breadth of 27,100 feet had to be accommodated within a horizontal distance of 27,000 feet, which by its hard and solid condition could take place only by fractures and dislocations of the strata.

This theory is verified by the fact, that a breadth of the horizontal strata of far more than the distance from outcrop to outcrop of the anthracite measures has been accommodated within the basin by numerous longitudinal faults or overlaps, all over the northern anthracite field, and the whole anthracite region.

An investigation of the workings of Forty Fort Colliery will convince one that the strata, near the foot of the underground slope on the eleven-foot seam, is dislocated by a longitudinal fault *B*, *Fig. 1*.

The vertical dislocation of the eleven-foot seam is about twelve to fifteen feet and consequently the whole series of strata is dislocated similarly. The fault *B* undoubtedly also intersected and dislocated the ancient river bed about the slope as demonstrated in *Figs. 1* and *2*.

Most probably the fault *B* is identical with the longitudinal fault developed by the adit of Harry E. Colliery many years ago, yet to be investigated. Two more longitudinal faults have been developed in this colliery; one at the head of the inclined plane and the second one by the underground slope and workings. If fault *B* in Forty Fort Colliery is identical with the fault in the adit of Harry E. Colliery, then the two other faults referred to will have been developed also on the Baltimore seam in Forty Fort

Colliery by this time. Since my observations, four years ago, I have no knowledge of the developments.

Each of the faults in Harry E. Colliery referred to will show similar appearances as demonstrated in *Figs. 1* and *2*, and the ancient river bed shifted southwards and higher by each of them in accordance with the vertical dislocation of the strata.

The maps of the Second Geological Survey of Pennsylvania exhibit numerous anticlinals between Pittston and the western outcrop of the basin, but none of them is in existence; they are merely longitudinal faults, and therefore it is obvious that the elevation and horizontal position of the ancient river bottom about Nanticoke must be quite different from the elevation and position in Forty Fort Colliery. Of course, the fall of the ancient river between those points might have been slight, moderate, or considerable, and the relations of the faults to the ancient river bed will prove to be in accordance with the vertical dislocation of the strata, which could be demonstrated only by a longitudinal section of the ancient river bottom. Nevertheless, each of the longitudinal faults, marked as anticlinals on the maps of the Second Geological Survey of Pennsylvania, will require especial consideration in order to avoid costly incidents in mining.

Undoubtedly, the sand and gravel of the ancient river bed at its inlet and outlet are still in connection with the Susqehanna River and also with those creeks which intersect the curb or northern outcrop of the carboniferous formation, hence the gravel layer must be filled with water constantly, and tapping the gravel by mine workings necessarily must cause flooding of the mine to a greater or less extent.

The danger of the ancient river bed is pretty well appreciated, and to avoid flooding of the mines and great loss of property considerable pillars of coal have been left unmined and are wasted forever.

Assuming that on the eleven-foot seam the coal pillars of at least 150 yards on the dip and of the Baltimore seam on each bank of the ancient river forty yards of coal are

left unmined, both seams yielding twelve feet of coal, the loss of tonnage per mile along the ancient river bed would be about:

	Cubic Yards.
Eleven-foot seam, 120 pillars, 150 × 6 × 2, ...	= 216,000
Baltimore seam, 1,760 × 80 × 2, ...	= 281,600
	497,600

equal to about 400,000 tons of marketable coal.

These coals could be mined very advantageously, for no additional investment would be required.

In order to lessen the waste to the Commonwealth and at the same time to lessen the danger constantly impending over those mines operating in the neighborhood of the ancient river, I offer the following suggestions:

Perhaps six, eight or ten pillars of the eleven-foot seam, below the ancient river bottom in Forty Fort Colliery, or in another suitable locality, ought to be robbed properly in order to secure a perfect break of the ancient river bottom. The great weight of the overlying clay certainly would produce a precipitation of the strata of from two to four feet, the gravel of the ancient river bottom would become mixed with clay and its connection with the Susquehanna River "shut up" almost completely. *Fig. 3.*

The next robbing of pillars and breaking down of the ancient river bottom would accomplish a complete "shut up" of the water from the Susquehanna River.

A break of the ancient river bottom about the town of Luzerne would have similar effects against the water from the higher ancient river bottom and from the mountain creek eventually; the water of moderate quantity of the gravel of the ancient river bottom would remain stagnant and all the coal between those breaks and on the right bank of the Susquehanna River, excepting the justified loss in mining, could be mined with safety.

The four to six feet thick lignite bed of Russia, mentioned already, is overlaid by a clay roof of variable thickness with local pockets of quicksand of from thirty to eighty feet thick, but not a gallon of water from the quicksand or from atmospheric precipitations has entered. the mines by

the breaks and precipitations of the surface caused by robbing of the coal bed.

The lignite bed of Bohemia, referred to, is from thirty to fifty feet thick, with a roof of clay from a few feet to 400 feet thick, which mostly is overlaid by heavy water carrying gravel from the mountain streams. Many acres of surface have precipitated from ten to fifteen feet by the incomplete robbing of the big coal deposit, but during eight years I never learned that surface water, or even water from the mountain streams had entered the mines by those breaks or funnels of the surface.

The outlay to carry out the above suggestions would be redeemed many times, and there is no doubt at all that cooperation of the land owners and coal operators would be rewarded by a great success of the mining industry.

PHILADELPHIA, September, 1892.

HOW THE EARTH IS MEASURED.*

BY PROF. J. HOWARD GORE.

[*A lecture delivered before the Franklin Institute, November 30, 1891.*]

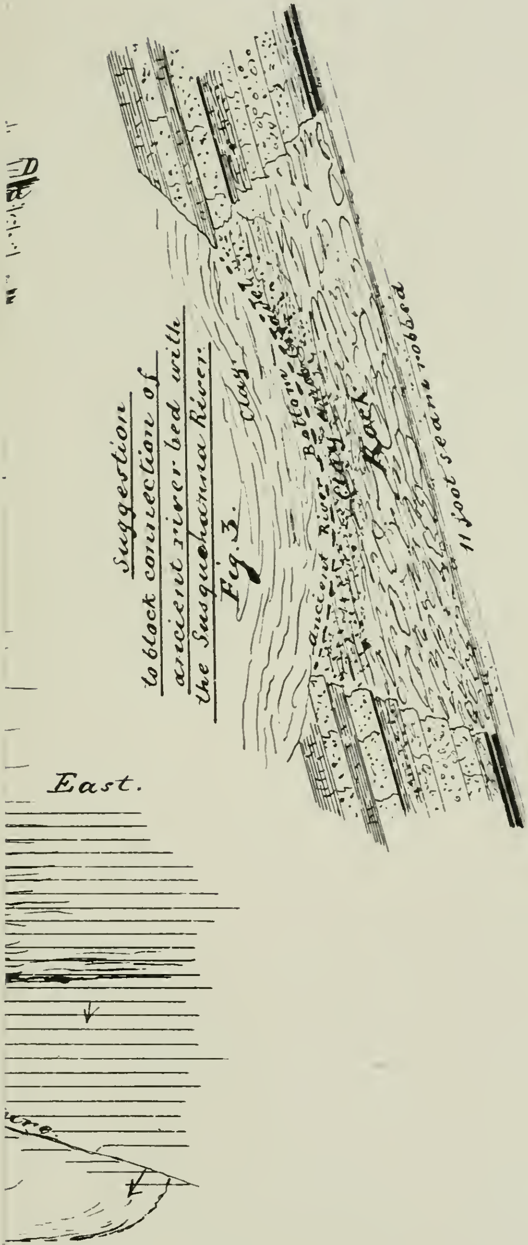
The lecturer was introduced by Professor Frazer, and spoke as follows:

From the time the infant brain throbs with sentient energy while reaching with its questioning eye or grasping hand after the unknown until the feeble mind no longer directs the dimmed vision or commands the palsied arm there is a longing to know the nature of all that surrounds us.

The air we breathe, the water that slakes our thirst, the sky that hems us in have been the subjects of many anxious thoughts: the stars that stud the heavens, the moon with its changing phases and the sun in his daily course have

* Certain portions of this paper are taken from the author's work on *Geodesy* published by Houghton, Mifflin & Co.

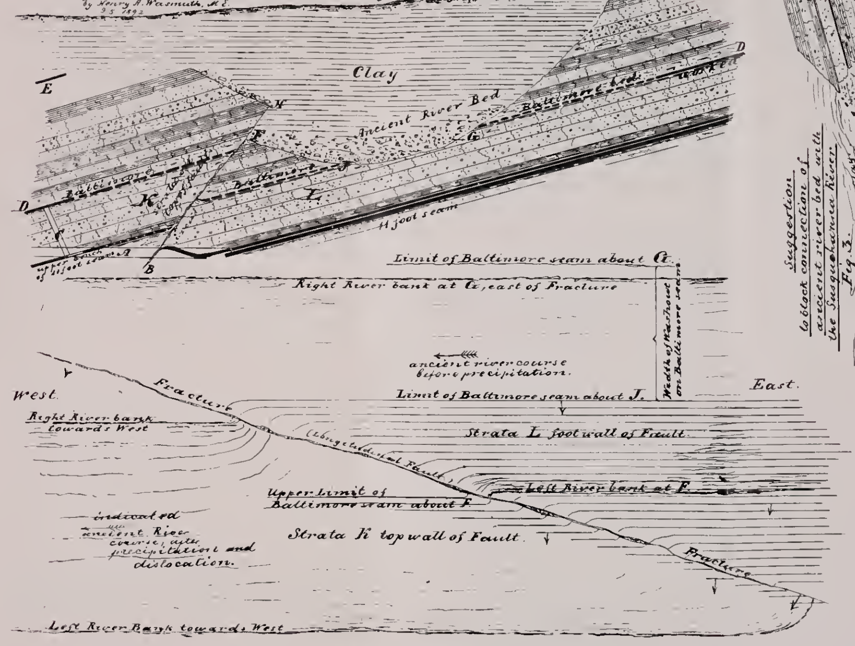
(Wasmuth.)



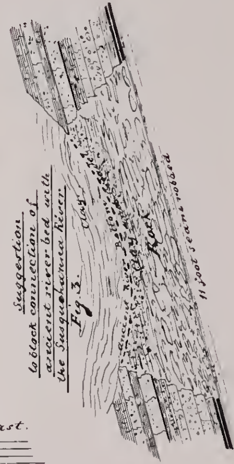
Suggestion to block connection of ancient river bed with the Susquehanna River.
Fig. 3.

Section of Cross Cut at foot of underground slope on 11 foot seam of Forty Fort Colliery. Fig. 1.

by Henry A. Wasmuth, M. E.



Horizontal Section at F. Fig. 2.



taken their places before the symbol of interrogation. And in the enlarging catalogue of queries there is ever present: What is the earth? What is its size? What is its shape?

The speculative Greek, with his all-sufficient Pantheon, placed it on Atlas' shoulder and was content or rolled it amongst crystalline balls to the music of the spheres. The contemplative Hindoo found it a fit subject for theories, and so have every peoples until Copernicus fossilized theory into fact by making the earth globular revolving in an orbit, and Newton holding it in place by the principle of universal gravitation.

To a person on a great eminence the earth appears as a vast plain, with the horizon supporting the sky as a dome-shaped roof. This appearance has been noticed by peoples at all times, and has called into existence flat-earth theories without number. A spirit of patriotism has prompted all to make one's own country occupy the most prominent geographical position and assume the maximum importance. Complimentary and laudatory myths have been invented by each tribe to account for the formation of its own country, while averring that all other tribes occupy insignificant areas formed of the useless fragments their builders graciously donated. Nor has this spirit been restricted to unlettered tribes; it showed itself long after the art of map-making was known, rendering it possible to determine from what country a map emanated by the relative sizes of the countries thereon. Likewise, as one looks out from a suitable position, one sees the horizon like a circle whose centre is the observer, and the sky above apparently a globe with the same centre. Thus it is that the Hindoos at the equator and the Scandinavians near the pole apply each a name to their own country which signifies the "central habitation."

The "hub" theory is not restricted to one country alone. The Greeks made Olympus the centre, the Egyptians Thebes, the Assyrians Babylon, the Hebrews Jerusalem; while the Chinese have regarded their land as the central empire since the time they sent astronomers to the four points of the compass to locate the equinoxes and the solstitial points.

One of the most primitive ideas regarding the earth represented it as an immense plain, or flat island, surrounded on all sides by an interminable ocean. This ocean in the minds of the Greeks was only a river, called Okeanos, and into this the sun made each night a plunge, to arise in the morning on the opposite side of the earth. At the extremities and borders were placed the "fortunate isles," or imaginary regions inhabited by giants, pigmies, and such mythical creatures as a vivid imagination could call into being. But when men began to have experience of the sea by navigation, the horizon always observed as circular led to the notion that the ocean was bounded, and the whole earth came to be represented as a circle, beneath which were roots reaching downward without end.

The cooling of the sun from his daily bath demanded some change in the material into which he plunged. And as he could not go down on one side and come up on the other without making the subterranean journey, some provision had to be made for his passage. It was easy to imagine a tunnel through which he could pass, but as soon as the progressive and retrograde movements in his places of setting and rising were recognized, it was necessary that the support of the earth be honeycombed with passages. The Buddhist priests declared that the sun passed between the pillars which supported the earth. And no sooner did they find this theory acceptable than they applied it to their ends. For, said they, these columns are sustained by virtue of the sacrifices which were made to the gods, and any indifference on the part of the worshippers might cause a collapse of the earth.

The ancient Greenlanders affirmed that the earth is upheld by pillars which are so consumed by time that they crack, thus quaking the earth; and were it not for the incantations of the magicians, the earth would long since have broken down. Thus we see a myth reaching

> "From Greenland's icy mountains
> To India's coral strand."

The Hindoos held the earth to be hemispherical, and to

be like a boat turned upside down upon the heads of four elephants, which stood on the back of an immense tortoise. This support, like a superficial answer, was sufficient until some curious questioner insisted upon knowing upon what the tortoise rested. The answer, upon the universal ocean, was soon proffered and gladly accepted, until the application of the further test, on what does the ocean stand? The ultimatum was then reached; the theory so boldly advanced and so ingeniously sustained needed a foundation principle; this it received in a shape that stilled further doubts and strengthened the whole superstructure: What supports the ocean? Why, it goes all the way to the bottom. This form of reply did not disappear with those who first made it, nor has it found a place in earth theories alone. Almost every science has advanced its line of interrogation points until a final all-sufficient answer is given, or an accepted axiom quoted.

Anaximander, a philosopher of the sixth century before Christ, represented the earth as a cylinder, the upper face only being inhabited. By some process now not known he computed its proportions, and gave as the result that its height was one-third of its diameter, and that it floated freely in the centre of the celestial vault. The doctrine of "sufficient reason" prevailed then, or was invented to fit this particular case, because when asked why this cylinder did not tip over, he replied that in the absence of a reason why it should tip in any one direction rather than in another, it did not tip at all, hence remaining in this state of helpless indecision. A fellow-philosopher, recognizing the importance of air in the economy of nature, supported the cylindrical earth of Anaximander on compressed air, which, owing to the vague and apparently imponderable character of air, did not suggest the need of a resting place for this air cushion.

Aristotle relied more upon fancy than upon fact, and deduced conclusions from logic and the nature of things rather than from observation. He reasoned from what he deemed natural to what must be or is. In answer to the question, Is the earth at rest? he replied, "The earth is

in repose, because we see it to be so, and because it is necessary that it should be, since repose is natural to the earth." He also affirmed that a circle is a perfect line, being uninterrupted and without ends; and, therefore, the stars, created by God to endure forever, must have an eternal motion, and being perfect creations they must move in the perfect line—the circle. The heavens, also, possessing this divine attribute of perpetuity, must move in a circle. Then, as a grand climax, he asserted that since in every revolving circle there is a point of absolute repose, the centre, the earth, being at rest, must occupy this central point.

Strabo, the geographer, who made the first century of the present era illustrious by his maps, declared the earth to be spherical, for in all his investigations and study regarding the travels of sailors and explorers he found no mention of the end of the earth. To him it appeared central and motionless, and in his consistent ignorance he unyieldingly affirmed that the entire habitable globe was represented on his maps, and was in shape like a cloak 8,000 miles long and 3,600 miles in width, the greater dimension being from east to west; hence our term longitude for degrees counted in that direction.

Bede, known as the Venerable, who lived in the eighth century, regarded the earth as formed upon the model of an egg. Being an element, it is placed in the middle of the universe as the yolk is in the middle of the egg; around it is the water, like the white surrounding the yolk; outside that is the air, like the membrane of the egg; and around all is the fire, which closes it in as does the shell. The earth, being thus in the centre, receives every weight upon itself; and though by its nature it is cold and dry in its different parts, it acquires, accidentally, different qualities; for the portion which is exposed to the torrid action of the air is burned by the sun, and is uninhabitable; its two extremities are too cold to be occupied, but the portion that lies in the temperate region is habitable. The ocean, which surrounds it by its waves as far as the horizon, divides it into two parts, the upper of which is inhabited by us, while

the lower is inhabited by our antipodes; although not one of them can come to us, nor one of us go to them.

As in other theories, a support was needed. To meet this requirement Edrisi, an Arabian geographer, broached the idea that the egg-like earth floats in the great ocean as in a basin.

Although we are told that Pythagoras and Thales taught that the earth was spherical, we see that their teaching was without avail on this point for nine centuries, while the shape of the earth was the play of many foolish fancies. Bede again rounded it off and gave to it the egg shape which it retained in the minds of men for 1,000 years. Many of these theories were so erroneous that they were in nowise links in a great chain which could bind all peoples into unanimity of belief. But while many were beating time without marching, others were making progress along hopeful lines.

Now that the development of ideas had carried men far enough to accept a spherical globe, it was only natural that speculations were rife as to its size, and it was equally natural that some one should come forward with a method for determining this magnitude; and while this method might in itself be inaccurate or unsatisfactory, yet it would serve as a quickening force in the elaboration of better and still better plans.

Before attempting to measure the entire earth it was necessary that considerable success should have been met with in measuring limited portions of its surface. Just when this art was first practised is hard to ascertain; probably when Joshua was sent to spy out the land, he had in view quantity as well as quality.

We are told by Herodotus that the credit of discovering geometry belongs to the Egyptians, who found need of its principles in the restoration of those boundaries of fields which were obliterated by the overflow of the Nile. He also gives us the method of procedure when the river god consumed portions of a man's landed possessions. "If the river carried away any portion of a man's lot, he appeared before the king and related what had happened, upon which

the king sent persons to examine and determine by measurement the exact extent of the loss; and thenceforth only such rent was demanded of him as was proportionate to the reduced size of his land. From this practice, I think, geometry first became known in Egypt, whence it passed into Greece."

With the acceptance of the belief that the earth was spherical came the notion that by finding the length of 1° on the earth's surface a simple multiplication by 360 would give the entire circumference, and this circumference being the same for the same sphere the measurement of 1° would suffice for the determination of the size of the earth.

Following out this idea, Eratosthenes communicated in 276 B.C. a value for the earth's circumference, followed in 135 B.C. by Posidonius, as results of approximate measures and erroneous observations.

Just here we must take a long step chronologically but not geographically. The exact sciences ceased to be cultivated in Greece and Egypt. They slumbered for centuries and awakened in Arabia. When the Arabians adopted the Mohammedan religion they became ambitious for mastery not alone in the field of battle, but in the arts and sciences. They embraced, extended and utilized the knowledge they found during their occupation of Egypt. They preserved trigonometry from oblivion and handed it down to us in its present shape, while to them we are indebted for the beginning and early development of practical astronomy. The Arabians reached their zenith under Caliph Almamon. He was not only a scholar, but a patron of the sciences, and assembled about him the most learned men of that period, among whom were Acaresimi, Alfraganus and Albategni.

This wise caliph was the next to make a contribution to the world's knowledge of the size of the earth. In 819 he imposed upon his astronomers the task of measuring a meridional arc on the plain of Singar by the Arabian Sea. They divided themselves into two parties, and starting from a given point, one party went north, measuring with wooden rods as they went, the other due south, likewise

measuring as they went. Each party continued, the former until they reached a point where the altitude of the pole was just *1*° higher than it was at the starting point, while the other did not stop until they found a place where the altitude had decreased by *1*°. Thus we see both groups had gone just a degree. The northward party had measured fifty-six miles, the southward, fifty-six and two-thirds miles.

It is said that they repeated their measurements and obtained identically the same results. However, others affirm that, appreciating the impracticability of the successful discharge of their duties, they adopted the value given by Ptolemy, which is perhaps about the mean of the two just given.

The method here described possessed geodetic features far in advance of those employed by the Greek mathematicians, but we have no information regarding the way in which the altitude of the pole was determined. From a lack of exact data as to the length of their unit, we are unable to form any opinion as to the accuracy of their result.

For 700 years speculation slumbered, and investigation was ignored. A cloud of ignorance hung over the world like a pall, and the attainments of the earlier inhabitants did not even remain as a shadowy dream. The discovery of mathematical writings left in Spanish cloisters by their Moorish invaders awakened some interest in the study of the exact sciences, and from the oblivion of the dark ages arose, Phœnix-like, the genius of that grander culture then begun, now unfinished.

In the opinions of men the earth was a plane, and again there was that painful, tedious uplifting of the benighted people to the realms of truth. Fortunately, the demonstrations were not left to the theorist alone; the science of navigation had by this time enabled men to venture beyond their littoral thoroughfares, and Magellan, circumnavigating the world in his three-years' voyage, placed beyond the confines of hypothesis the globular form of the earth.

In the ignorance of methods of determining differences

of longitude, it was impossible to ascertain the amplitude of an arc extending east and west. The determination of latitudes was an early art, but the measuring of an arc of meridian whose amplitude was, centuries ago, approximately ascertainable was limited to direct measurement.

Inasmuch as the task of finding a suitable stretch of country fulfilling the required conditions was difficult, the number of direct determinations were few, being restricted to Fernel, 1525, and Norwood, 1633.

[*To be continued.*]

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

By Emrick A. Werner.

[*Continued from p. 311.*]

EXAMPLES.

Before beginning with the calculation of the stresses, it must be shown how are caculated the reactions and moments of the external forces and how the loadings can be reduced to concentrated panel loads.

Moment Table.—

Calculation of Moment Table.—

$$R_{\mathrm{m}} = a\,W + b\,(W + W') + c\,(W + W' + W'') + \ldots.$$

$$R'_{\mathrm{m}} = a\,W' + (a + b)\,W'' + (a + b + c)\,W''' + \ldots$$

$a, b, c \ldots$ distances between the loads $W', W'', W''' \ldots$

Check. $R_{\mathrm{m}} + R'_{\mathrm{m'}} = W_{(\mathrm{m+m'})}$ = total load on $(m + m')$ multiplied by that distance.

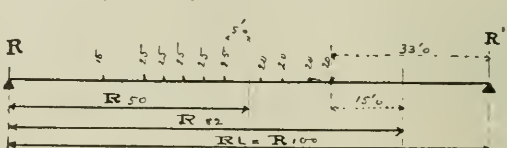


FIG. 2.

12,357
9,643

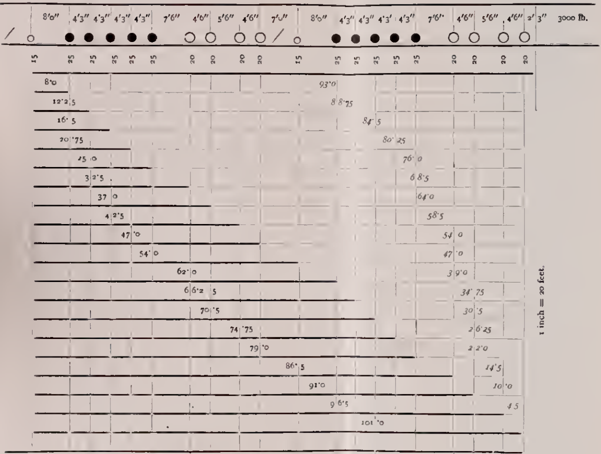
22,000
= 50.

= 3,247
× (47 —

19,017

21,829
15,671

37,500
ıaking



R_m	120	290	566	949	1,437	2,487	3,207	4,197	5,097	6,637	8,517	9,622	10,834	12,151	13,575	16,275	17,985	20,185	22,075
W	40	65	90	115	140	160	180	200	220	235	260	285	310	335	360	380	400	420	440
R'_m	200	506	919	1,437	2,063	2,712	3,452	4,303	5,242	6,052	7,602	9,259	11,021	12,890	14,865	16,595	18,415	20,345	22,365

FIG. 1.

Application for Different Positions of the Loads.—

$$R_{50} = 5 \times 140 + R_{25} = 700 + 1.437 = 2,137$$

$$R_{100} = R\,l = 33 \times 220 + R_{47} = 7,260 + 5,097 = \quad 12,357$$

$$R'_{100} = R'\,l = 20 \times 220 + R'_{47} = 4,400 + 5,243 = \quad 9,643$$

$$R\,l + R'\,l = W\,l = 220 \times 100 = \quad 22,000$$

The same check can be applied to R_{50}, in making $l = 50$.

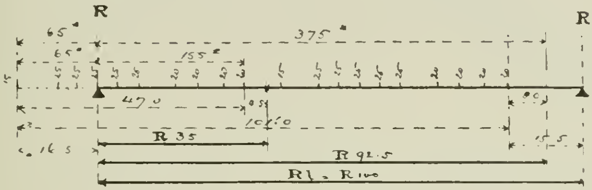


FIG. 3.

$$R_{35} = 4{\cdot}5 \times 155 + R_{47} - [R_{16\cdot5} + 65 \times (47 - 16{\cdot}5)] = 3,247$$

Note.—155 = load *on the span* before x including load on x $65 \times (47 - 16{\cdot}5) = W_m$ m counted from R_{47}.

$$R_{92\cdot5} = 8 \times 375 + R_{101} - [R_{16\cdot5} + 65 \times (101 - 16{\cdot}5)] = 19,017$$

$$R_m = Rl = 15{\cdot}5 \times 375 + R_{101} - [R_{16\cdot5} + (101 - 16{\cdot}5) \times 65] = 21,829$$

$$R'\,100 = R'l = R'_{101} - R'_{12\cdot25} - 16{\cdot}5 \times (440 - 65) = 15,671$$

$$\text{Check } Rl + R'l = Wl = 375 \times 100 = 37,500$$

The same check can be applied to R_{35} and $R_{92\cdot5}$ in making $l = 35$ resp. $92{\cdot}5$.

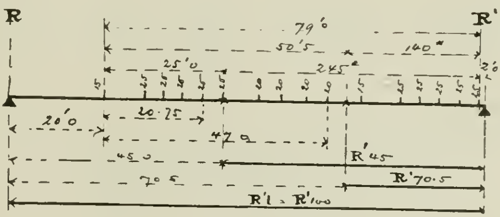


FIG. 4.

$$R'_{45} = R'_{79} - R'_{20\cdot75} - 25 \times (360 - 115) = 7{,}303$$

Note.—$R'_{20\cdot75}$ never includes the load on x.

$$R'_{70\cdot5} = R'_{79} - R'_{47} - 50\cdot5 \times (360 - 220) = 2{,}552$$

$$R'_{100} = R'l = 20 \times 360 + R'_{79} = 22{,}065$$

$$R100 = Rl = 1 \times 360 + R79 = 13{,}935$$

$$\text{Check } Rl + R'l = Wl = 360 \times 100 = 36{,}000$$

The same check can be applied to R'_{45} and $R^1_{70\cdot5}$ in making $l = 45$ resp. $70\cdot5$.

CALCULATION OF REACTIONS AND MOMENTS.

Vertical reactions R

$$R = Rl \div l$$

Horizontal reaction

$$Hf = R\ l \,.\, \frac{1}{2} - W_1 \left(\frac{l}{2} - g_1\right) - W_2 \left(\frac{l}{2} - g_2\right) =$$

$$= R'l \,.\, \frac{1}{2} - W_3 \left(\frac{l}{2} - g_3\right) = \frac{R'\,l}{2} - R_f$$

Moments.—

$$M_x = R\,x - W_1\ (x - g_1) - H\,y = R\,l \,.\, \frac{x}{l} - R_x - Hf \,.\, \frac{y}{f}$$

$$= R'\,(l - x) - W_2\,(g_2 - x) - W_3\,(l - x - g_3) - H\,y$$

$$= R'l \,.\, \frac{x}{l - x} - R'_x - \left(\frac{R'\,l}{2} - R'_f\right) \frac{y}{f}$$

f = rise of arch = height of top hinge above abutment hinges.

Concentrated Panel Loads.—

$$p = \frac{R_{x + \Delta x} - R_x}{\Delta x'} - \frac{R_x - R_{x - \Delta x}}{\Delta x}$$

Δx, $\Delta x'$ = length of panels.

LOADS AT REST.

I.

Upright Arch with Circular Line of Thrust.

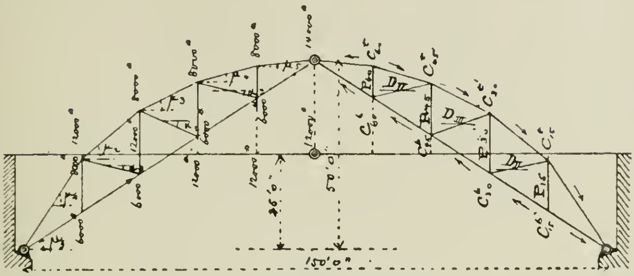


FIG. 5.

One hundred and fifty feet span, 10 panels 15 feet each, 50 feet rise of arch.

The thrust is taken up fully by the upper chord which has thus the form of the circular line of thrust.

The arch shall have *only diagonals in tension.*

The dead load is taken as load at rest.

It is assumed to 26,000 pounds per panel point.

Of the dead load 92,000 pounds are acting on the roadway, 8,000 pounds on the top chord, and 6,000 pounds on the bottom chord. The roadway is twenty-five feet above the abutment hinges.

h = depth of truss.

h	x	y	f	$\frac{y}{f}$	μ		α		
					tan.	*cos.*	*tan.*	*cos.*	
13·54	15	23·54		0·4708	1·5693	0·537	—	—	$tan. f = \frac{50}{75} = \frac{2}{3}$
16·40	30	36·40		0·7280	0·8573	0·759	0·2360	0·973	$cos. f = 0·832$
14·26	45	44·26	50·0	0·8052	0·5240	0·885	0·4266	0·919	
8·60	60	48·60		0·9720	0·2893	0·960	0·2840	0·961	
0·0	75	50·00		1·0000	0·0933	0·995	—	—	

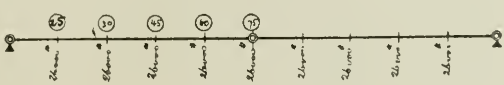


FIG. 6.

$$R\,l = R'\,l = 17{,}550$$
$$R_{15} = 0$$
$$R_{30} = 390$$
$$R_{45} = 3 \times 390 = 1{,}170$$
$$R_{60} = 6 \times 390 = 2{,}340$$
$$R_{75} = 10 \times 390 = 3{,}900$$
$$H\,f = R\,\frac{l}{2} - R_{75} = 4{,}875 \div 50 = H = 97{\cdot}5$$
$$H\,f\,.\,\frac{y}{f} = H\,y_{15} = 2{,}295{\cdot}15$$
$$H\,y_{30} = 3{,}549$$
$$H\,y_{45} = 4315{\cdot}35$$
$$H\,y_{60} = 4738{\cdot}5$$

Horizontal Chord Stresses.—

Bottom Chord:

$$C_x = \left(\frac{M}{h}\right)_x$$

H being taken up fully by the top chord.

$$\left(\frac{M}{h}\right)_x = R\,l\,.\,\frac{x}{l} - R_x - H\,y = R'\,l\,\frac{x}{l - x} - R'_x - H\,y$$

$$C_{15} = \frac{1}{13{\cdot}54}(1{,}755 - 0 - 2{,}295) = -\,39{,}900$$
$$C_{30} = -\,26{,}200$$
$$C_{45} = -\,15{,}300$$
$$C_{60} = -\,6{,}800$$

Top Chord:

$$C_x = \left(\frac{M}{h}\right)_x - H$$

$\left(\frac{M}{h}\right)_x$ being negative produces tension in the top chord, hence:

$$C_{15} = -\,97{,}500 + 39{,}900 = -\,57{,}600$$
$$C_{30} = -\,71{,}300$$
$$C_{45} = -\,82{,}000$$
$$C_{60} = -\,90{,}700$$
$$C_{75} = -\,97{,}500$$

Horizontal Stress in the Diagonals.—

$$D_x = C_x - C_{x-\Delta x} = \left(\frac{M}{h}\right)_x - \left(\frac{M}{h}\right)_{x-\Delta x}$$

From Bottom Chord:

$$D_2 = -26{,}200 + 39{,}900 = +13{,}700$$

$$D_3 = +10{,}700$$

$$D_4 = +\ 8{,}700$$

Check from Top Chord:

$$D_2 = 71{,}300 - 57{,}600 = +13{,}700$$

and in the same way D_3 and D_4.

D being positive the diagonals run from the left to the right. From this direction of the diagonals follows the direction of the chord stresses, as shown in *Fig. 5*.

Vertical Stresses in the posts.

From Top Chord:

$$P_{15} = C_{15} \tan \mu_1 - C_{30} \tan \mu_2 - D_2 \tan \alpha_2 = 26{,}000 \text{ pounds.}$$

$$P_{30} = C_{30} \tan \mu_2 - C_{45} \tan \mu_3 - D_3 \tan \alpha_3 = 13{,}500 \text{ pounds.}$$

$$P_{45} = C_{45} \tan \mu_3 - C_{60} \tan \mu_4 - D_4 \tan \alpha_4 = 14{,}200 \text{ pounds.}$$

$$P_{60} = C_{60} (\tan \mu_3 - \tan \mu_4) \qquad = 17{,}800$$

From Bottom Chord (check):

$$P_{15} = (C_{15} - C_{15}) \tan \mu_f - p = o - 26{,}000 \text{ pounds} = 26{,}000 \text{ pounds.}$$

$$P_{30} = (C_{30} - C_{15}) \tan \mu_f + D_2 \tan \alpha_2 - p = 12{,}400 - 26{,}000 = = 13{,}600$$

$$P_{45} = (C_{45} - C_{30}) \tan \mu_f + D_3 \tan \alpha_3 - p = 11{,}700 - 26{,}000 = = 14{,}300$$

$$P_{60} = (C_{60} - C_{45}) \tan \mu_f + D_4 \tan \alpha_4 - p = 8{,}300 - 26{,}000 = = 17{,}700$$

As the direction of the stresses in the chords cannot be foretold, but is found from the direction of the diagonals, which depends upon the sign of D, it is not possible to give the stresses in the chord members before D is calculated.

With these data, we find now the stresses in the members.

Bottom chord:

$$\frac{C}{\cos \mu_f} = \frac{C}{0{\cdot}832}$$

the members are under compression, C being negative.

First panel = second panel = 39,900 ÷ 0·832 = 48,000

Third panel = 31,900 pounds. Fourth panel = 18,700

Fifth panel = 8,200 pounds.

Top chord:

$$\frac{C_x}{\cos \mu_x} \text{ — compression.}$$

First panel = 57,600 ÷ 0·537 = 107,300

Second panel = 94,000

Third panel = 92,700

Fourth panel = 94,500

Fifth panel = 91,200 pounds.

Diagonals:

$$\frac{D_x}{\cos \alpha_t} \text{ — Tension —}$$

Second panel = 13,700 ÷ 0·236 = 58,100

Third panel = 25,200

Fourth panel = 30,700

Posts:

P_{15} = 26,000 — 20,000 = 6,000 tension.

P_{30} = upper part = 13,500 — 8,000 = 5,500 tension.

lower part = 6,000 — 12,400 = 6,400 compression.

P_{45} = 14,200 — 8,000 = 6,200 pounds.

P_{60} = 17,800 — 8,000 = 9,800 pounds.

Computing these stresses we have the following strain sheet for dead load.

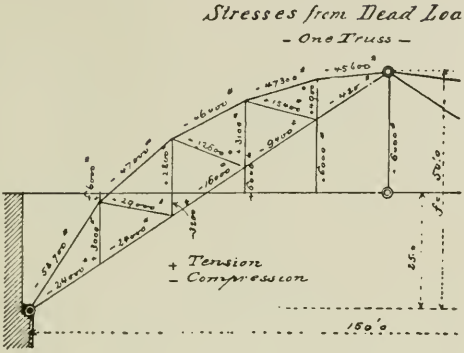


FIG. 7.

II.

Upright Arch with Parabolic Line of Thrust.

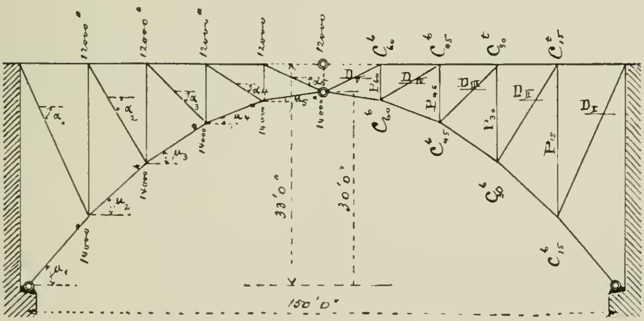


FIG. 8.

One hundred and fifty feet span, 10 panels 15 feet each, 30 feet rise of arch.

The thrust is taken up fully by the bottom chord. The arch shall have only diagonals in tension.

The dead is the load at rest. It is assumed to 26,000 pounds per panel point. Of this load 12,000 pounds are acting at the top chord, 14,000 pounds at the bottom chord.

h = depth of truss.

x	y	f	$\frac{y}{f}$	h	μ		a	
					tan.	cos.	tan.	cos.
15	10·8	30·0	0·36	22·2	0·72	0.811	1·48	0·559
30	19·2		0·64	13·8	0·56	0·872	0·92	0·736
45	25·2		0·84	7·8	0·40	0·928	0·52	0·887
60	28·8		0·96	4·2	c·24	0·972	0·28	0·963
75	30·0		1·0	0·0	0·08	0·997	0·20	0·981

(See Fig. 6.)

$$R\,l = R'l = 17{,}550$$

$$R_{15} = 0$$

$$R_{30} = 390$$

$$R_{45} = 1{,}170$$

$$R_{60} = 2{,}340$$

$$R_{75} = 3{,}900$$

$$H f = \frac{R\,l}{2} - R_{75} = 4{,}875 \div 30 = H = 162{,}500 \text{ pounds.}$$

$$H f \frac{y}{f} = H y_{15} = 1{,}755$$

$$H y_{30} = 3{,}120$$

$$H y_{45} = 4{,}095$$

$$H y_{60} = 4{,}680$$

Horizontal Stresses in the Chords.—

Top Chord:

$$C_x = \left(\frac{M}{h}\right)_x$$

$$C_{15} = 1{,}755 - o - 1{,}755 = o = C_{30} = C_{45} = C_{60} = C_{75}$$

Bottom Chord:

$$C_x = \left(\frac{M}{h}\right)_x - H = - H.$$

$$C_{15} = C_{30} = C_{45} = C_{60} = C_{75} = H = 162{,}500 \text{ pounds.}$$

Horizontal Stresses in the Diagonals.—

$$D_x = C_x - C_{x-\Delta x} = o$$

Stresses in the Posts.—

$$D = o$$
$$C = o$$
$$P = 26{,}000$$

Check from bottom chord

$$D = o$$
$$C = H$$
$$P = H\,(tan\ \mu_{x+\Delta x} - tan\ \mu_x) = 26{,}000$$

With these data we find the stresses in the members:

Top Chord.—Stress in all members equal to zero.

Bottom Chord

$$= \frac{C}{cos\ \mu} = \frac{H}{cos\ \mu}$$

First panel $= 162{,}500 \div 0{,}811 = 200{,}000$
Second panel $= 186{,}000$
Third panel $= 175{,}000$
Fourth panel $= 167{,}000$
Fifth panel $= 163{,}000$

Stress in Diagonals $= O$

Stress in all Posts

$$= P = 26{,}000 - 14{,}000 = 12{,}000 \text{ compression.}$$

Computing the stresses we find the following strain sheet for the dead load:

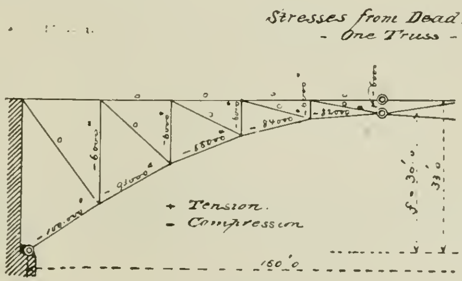


FIG. 9.

MOVING SINGLE LOADS.

I.

Upright Arch with Parabolic Line of Thrust.

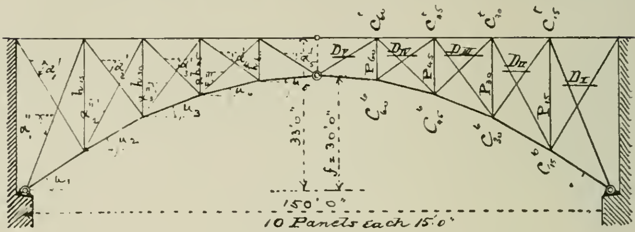


FIG. 10.

x	y	f	$\frac{y}{f}$	h	μ tan.	μ cos.	a' tan.	a' cos.	a'' tan.	a'' cos.	
15	10·8		0·36	22·2	0·72	0 811	1·48	0·559	2·20	0·414	I
30	19·2		0·64	13·8	0·56	0·872	0·92	0·736	1·48	0·559	II
45	25·2	30·0	0·84	7·8	0·40	0·928	0·52	0·887	0·92	0·736	III
60	28·8		0·96	4·2	0·24	0·972	0·28	0·963	0·52	0·887	IV
75	30·0		1·00	—	0·08	0·997	0·20	0·981	—	—	V

The arch has 150 feet span, 10 panels 15 feet each, 30 feet rise. The arch shall have only diagonals in tension.

The thrust is taken up fully by the lower chord, which has the form of the line of thrust.

The dead load is assumed at 26,000 pounds per panel point. The stresses resulting from it are calculated under loads at rest.

The moving loads are the two engines of the moment table followed by 3,000 pounds per lineal foot of bridge. (See *Fig. 1.*)

The above diagram gives all the necessary data for the calculation.

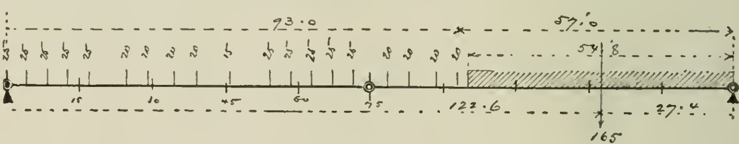


FIG. 11.

Vertical Reactions.—The first driver over the left abutment makes W and Rl a maximum, and

$$R\,l = 49{,}306$$

$$R'\,l = 30{,}194$$

Hence

$$R = R\,l \div l = 328{,}700 \text{ pounds}$$

$$R \; minim. = 0$$

Horizontal Stress H of the Thrust.—

Maximum:

$$\frac{d\,H}{d\,g} = W - 2\,W_3$$

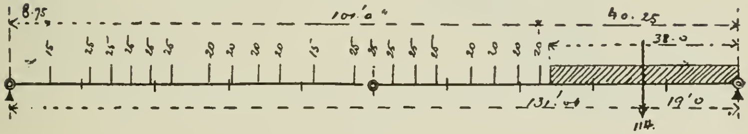


FIG. 12.

To the right of the dividing line (top hinge)

$$W = 554 \quad W_3 \; 294$$

To the left of the dividing line

$$W = 554 \quad W_3 \; 269$$

Whence

$$\frac{d\,H}{d\,g} = \left[\begin{array}{l} 554 - 588 < 0 \\ 554 - 538 > 0 \end{array} \right.$$

and

$$R\,l = 41{,}951$$

$$R'\,l = 41{,}149$$

Check

$$R\,l + R'\,l = 83{,}100 = W\,l = 554 \times 150$$

$$R_{75} = 9{,}622$$

$$R'_{75} = 9{,}222$$

$$H\,f = R\,\frac{l}{2} - R_{75} = R'\,\frac{l}{2} - R'_{75} = 11{,}354$$

$$H = 11{,}354 \div 30 = 378{,}500 \text{ pounds}$$

Minim. $H = o$

Horizontal Stress C in the Chords.—

Top Chord: $C_x = \left(\frac{M}{h}\right)_x$

As no thrust is taken up by the top chord H is equal to zero, and we find

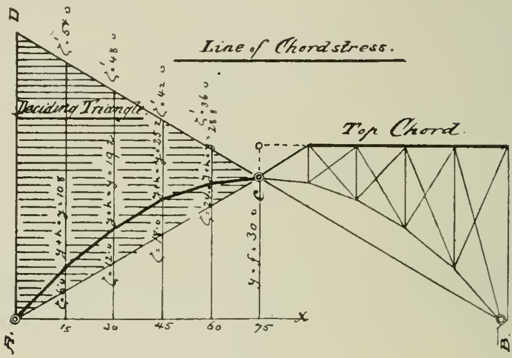


FIG. 13.

x	$\frac{\zeta' - y}{2f}$	$\frac{\zeta + y}{2f}$	$\frac{\zeta - y}{2f}$
15	+ 0·72	+ 0·28	— 0·08
30	+ 0·48	+ 0·52	— 0·02
45	+ 0·28	+ 0·72	— 0·12
60	+ 0·12	+ 0·88	— 0·08
75	o	o	o
	a	β	c

and have the general equation of the stresses in the top chord

$$\left(\frac{M}{h}\right)_x = a\, W_1\, g_1 + C\, W_2 + C\, W_3\, g_3$$

$$\left(\frac{M}{h}\right)_{15} = C_{15} = [0{\cdot}72\, W_1\, g_1 + W_2\,(15 - 0{\cdot}28\, g_2) -$$

$$- 0{\cdot}08\, W_3\, g_3]\,\frac{1}{22{\cdot}2}$$

$$\left(\frac{M}{h}\right)_{30} = C_{30} = [0{\cdot}48\ W_1 g_1 + W_2 (30 - 0{\cdot}52\ g_2) -$$

$$- 0{\cdot}12\ W_3 g_3] \frac{1}{13{\cdot}8}$$

$$\left(\frac{M}{h}\right)_{45} = C_{45} = [0{\cdot}28\ W_1 g_1 + W_2 (45 - 0{\cdot}72\ g_2) -$$

$$- 0{\cdot}12\ W_3 g_3] \frac{1}{7{\cdot}8}$$

$$\left(\frac{M}{h}\right)_{60} = C_{60} = [0{\cdot}12\ W_1 g_1 + W_2 (60 - 0{\cdot}88\ g_2) -$$

$$- 0{\cdot}08\ W_3 g_3] \frac{1}{4{\cdot}2}$$

Making $C = o$, we find g_m = *Maximum Line.*

Maxima.—

C_{15} *maximum.*

$$\text{Maximum line } g_m = \frac{1509}{28} = 53{\cdot}6$$

$$\text{Maximum span} = a + (g_m - a) = 53{\cdot}6$$

$$\left(\frac{d\,C}{d\,g}\right) max. = a\ W_1 - \beta\ W_2 = (a + \beta)\ W_1 - \beta\ W$$

$$= 25\ W_1 - 7\ W$$

W = total load on truss.

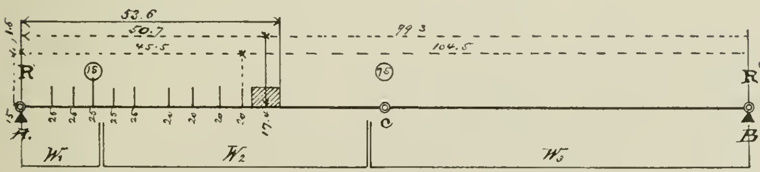


FIG. 14.

To the right of the dividing line $W = 222{\cdot}4\ W_1 = 75$

To the left of the dividing line $W = 222{\cdot}4\ W_1 = 50$

Whence

$$\left(\frac{d\,C}{d\,g}\right) = \left[\begin{array}{l} 1{,}557 - 1{,}875 < o^* \\ 1{,}557 - 1{,}250 > o \end{array}\right.$$

---

* In the same way the corresponding positions of the loads for C_{30}, C_{45}, C_{60}, max. are formed from $\frac{dC}{dg}$.

and C_{15} maximum with

$$R\,l = 27{,}542 \quad R'\,l = 5{,}817 \text{ check } R\,l + R'\,l = 222.4 \times 150 = $$
$$= 33{,}359$$

$$R_{15} = 319 \quad R_{75} = 10{,}862 \quad H\,f = \frac{R\,l}{2} - R_{75} = 2{,}909$$

$$H\,y = H\,f.\ \frac{y}{f} = 2{,}909 \times 0{\cdot}36 = 1{,}047$$

$$R'_{15} = 2{,}800 \quad R'_{75} = o \quad H'\,f = \frac{R'\,l}{2}\ R_{75} = 2{,}909$$

$$\left(\frac{M}{h}\right)_{15} = \left[R\,l\,.\ \frac{x}{l} - R_{15} - H\,y\right]\frac{1}{h} = 62{,}600 \text{ pounds}$$

$$\left(\frac{M}{h}\right)'_{15} = \left[R'\,l\ \frac{x}{l-x} - R'_{15} - H\,y\right]\frac{1}{h} = 62{,}600 \text{ pounds}$$

$$D_{\mathrm{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{0} = \left(\frac{M}{h}\right)_{15} = 62{,}600 \text{ pounds}$$

C_{30} *max.*—

$$\text{Maximum line } g_m = \frac{3{,}000}{52} = 57{\cdot}7$$

$$\text{Maximum span} = a + (g_m - a) = 57{\cdot}7$$

$$\frac{d\,C}{d\,g} = 25\ W_1 - 13\ W$$

First wheel of engine 50·75 from abutment A, last wheel of tender 3·75 from abutment A.

Fourth driver in point (30).

$$C_{30}\ max. = \left(\frac{M}{h}\right)_{30} = +\ 1894 \div 13{\cdot}8 = 137{,}300 \text{ pounds.}$$

$$D_{\mathrm{II}} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = 137{,}300 - 56{,}600 = +\ 80{,}700$$

C_{45} *max.*—

$$\text{Max. line } g_m = 62{\cdot}5.$$

$$\text{Max span} = a + (g_m - a) = 6{\cdot}25$$

$$\frac{d\,C}{d\,g} = 25\ W_1 - 18\ W$$

Third driver of first engine in point 45, last wheel of tender 14·5 feet from abutment A, followed by 3,000 pounds per foot for 12·2 feet.

$$C_{45}\ max. = 1{,}818 \div 7{\cdot}8 = 233{,}100 \text{ pounds} = \left(\frac{M}{h}\right)_{45}$$

$$D_{\mathrm{III}} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = +\ 107{,}000 \text{ pounds.}$$

C_{60} *max.*—

$$\text{Max. line } g_{\mathrm{m}} = 68{\cdot}2$$

$$\text{Max span} = a + (g_{\mathrm{m}} - a) = 68{\cdot}2$$

$$\frac{d\,C}{d\,g} = 25\ W_1 - 22\ W$$

First driver of first engine in point 60, second driver of second engine 1·75 from abutment A.

C_{60} *max.*

$$= 1{,}095 \div 42 = 260{,}600 \text{ pounds} = \left(\frac{M}{h}\right)_{60}$$

$$D_{\mathrm{IV}} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = +\ 52{,}400 \text{ pounds.}$$

Minima (Top Chord).

C_{15} *minim.*—

$$\text{Max. line } g_{\mathrm{m}} = 53{\cdot}6$$

$$\text{Minimum span} = \left(\frac{l}{2} - g_{\mathrm{m}}\right) + c = 96{\cdot}4$$

$$\frac{d\,C}{d\,g} = 7\ W - 9\ W_3$$

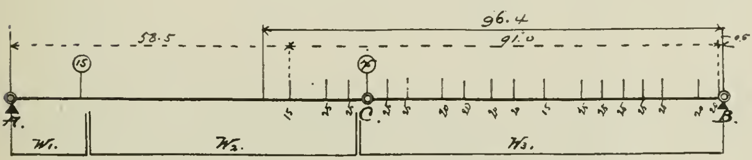


FIG. 15.

To the right of the dividing line (top hinge)

$$W = 400\ W_3 = 310.$$

To the left of the dividing line (top hinge)

$$W = 400\ W_3 = 335$$

Whence

$$\frac{d\,C}{d\,g} = \begin{cases} 2{,}800 - 3{,}015 < o^* \\ 2{,}800 - 2{,}790 > o \end{cases}$$

and with

$$R\,l = 18{,}185$$

$$R'\,l = 41{,}815$$

$$\text{check } R\,l + R'\,l = W\,l = 60{,}000 = 400 \times 150$$

$$R_{15} = o \quad R_{75} = 566 \quad H\,f = R\,\frac{l}{2} - R_{75} = 8{,}526$$

$$H\,y = H\,f\,.\,\frac{y}{f} = 3{,}069$$

$$R'_{15} = 35{,}815$$

$$R'_{75} = 12{,}382$$

$$H'f = R'\,\frac{l}{2} - R'_{75} = 8{,}526$$

$$C_{15} = \left(\frac{M}{h}\right)_{15} = \left(Rl\frac{x}{l} - R_{15} - H\,y\right)\frac{1}{h} = \left(R'l\,\frac{x}{l-x} - \right.$$

$$\left. - R'_{15} - Hy\right)\frac{1}{h} = -\,1{,}251 \div 22{\cdot}2 = 56{,}400 \text{ pounds.}$$

$$D_{\mathrm{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{15} = \left(\frac{M}{h}\right)_{15} = -\,56{,}400.$$

C_{30} *min.*—

Minimum span $= 92{\cdot}3$

$$\frac{d\,C}{d\,g} = 13\,W - 16\,W_3$$

(See Fig. 15.)

$$C_{30}\ min. = -\,1{,}820 \div 13{\cdot}8 = -\,131{,}900 \text{ pounds.}$$

$$D_{\mathrm{II}} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = -\,75{,}500 \text{ pounds.}$$

* In the same way the positions of the loads are found from $\frac{d\,C}{d\,g}$ for C_{30}, C_{45}, C_{60}, min.

C_{45} *min.:*

Minimum span $= 87\cdot5$ (see C_{15})

$$\frac{d\,C}{d\,g} = 6\ W - 7\ W_3$$

Second driver of first engine on top hinge, first wheel of second tender $0\cdot75$ from Abutment B.

$$C_{45}\ min. = -\ 1{,}744 \div 7\cdot8 = -\ 223{,}500 = \left(\frac{M}{h}\right)_{45}$$

$$D_{\text{III}} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{50} -\ 92{,}600$$

C_{60} *min.:*

Minimum span $= 81\cdot8$

$$\frac{d\,C}{d\,g} = 11\ W - 12\ W_3$$

First driver of first engine on top hinge, fifth driver of second engine four feet from Abutment B.

$$C_{60}\ min = -\ 1{,}086 \div 42 = -\ 25{,}8600 = \left(\frac{M}{h}\right)_{60}$$

$$D_{\text{IV}} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = -\ 40{,}600 \text{ pounds.}$$

Bottom Chord:

The full thrust being taken up in the bottom chord, we have

$$C_{\text{x}} = \left(\frac{M}{h}\right)_{\text{x}} - H$$

and

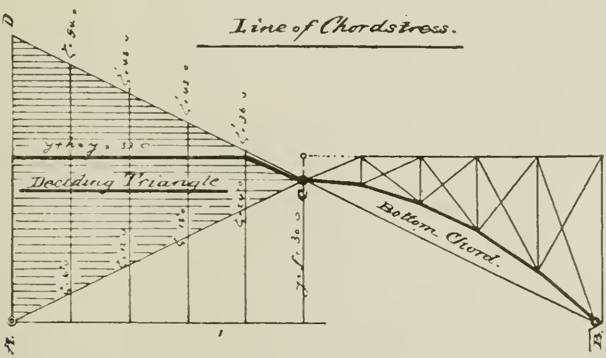


FIG. 16.

x	$\frac{\zeta' - (y + h)}{2f}$	$\frac{\zeta + (y + h)}{2f}$	$\frac{\zeta - (y + h)}{2f}$
15	+ 0·35	+ 0·65	— 0·45
30	+ 0·25	+ 0·75	— 0·35
45	+ 0·15	+ 0·85	— 0·25
60	+ 0·05	+ 0·95	— 0·15
	a	β	c

check a, β, c of top and bottom chord differ by

$$\frac{h}{2f}$$

The general equations of the stresses in the bottom chord are:

$$C_{15} = [0·35\ W_1 g_1 + W_2 (15 - 0·65\ g_2) - 0·45\ W_3 g_3] \frac{1}{22·2}$$

$$C_{30} = [0·25\ W_1 g_1 + W_2 (30 - 0·75\ g_2) - 0·35\ W_3 g_3] \frac{1}{13·8}$$

$$C_{45} = [0·15\ W_1 g_1 + W_2 (45 - 0·85\ g_2) - 0·25\ W_3 g_3] \frac{1}{7·8}$$

$$C_{60} = [0·05\ W_1 g_1 + W_2 (60 - 0·95\ g_2) - 0·15\ W_3 g_3] \frac{1}{4·2}$$

Making $c = 0$, we find the maximum line g_m and with it the maximum and minimum span of the stress as in the top chord stresses. As also in the bottom chord the third members of the equations are negative, the same expression for

$$\frac{dC}{dg} \text{ maximum}$$

and

$$\frac{dC}{dg} \text{ minimum,}$$

as for the top chord, are found.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, September 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Dr. Bruno Terne read an interesting and valuable paper, giving an account of the meeting of the Association of Agricultural Chemists, held recently in Washington. The paper included an historical account of the association and a critical consideration of the merits of the analytical methods approved by the association for the quantitative analysis of fertilizers. The paper was discussed by the author and Mr. Williams, of Wilmington.

The Section then adjourned. WM. C. DAY, *Secretary*.

PROCEEDINGS.

[*Stated meeting, held Tuesday, October 18, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18, 1892.

Dr. Wm. H. Wahl, President, in the chair.

The resignation of Mr. G. L. Norris was presented, and on motion was accepted by vote of the Section.

The Treasurer called attention to the name of a member whose dues have not been paid for two years; according to the by-laws the name was dropped from the list of members.

The President proposed for membership Mr. J. Benjamin Glavin, 1312 Passyunk Avenue, Philadelphia; the name was referred to the Committee on Admissions and Mr. Glavin was elected a member of the Section.

The Actuary of the Institute presented two bills from the Institute for subscriptions to various journals. The contraction of these bills having already been authorized by the Section, the bills were ordered paid and they were accordingly submitted to the Treasurer of the Section for payment. The Actuary also requested authority to pay for subscriptions to journals

from February of the present year to date. These bills amounted to a total of 59·40 marks. On vote the necessary authority was granted.

In view of the fact that Dr. Harvey Wiley, of the Agricultural Department, at Washington, is to lecture at the Franklin Institute on the evening of the 5th of December, of the present year, Dr. Terne suggested that it would be fitting for the Chemical Section to tender him a reception after the close of his lecture. The suggestion was favorably considered and on motion the President was requested to name a committee to consider the question of the arrangement and form of the reception; the committee was requested to report at the next meeting of the Section. The President named Dr. Terne, Dr. Jayne and Mr. Pemberton as members of this committee.

Mr. Geo. W. Whyte, of the Camden Iron Works, then read a paper entitled "The Washing of a Southern Coal; Comparison of Laboratory Results with those of Actual Washing Test." The paper gave some valuable results of quite a large amount of experimental work and was listened to with much interest by the members present.

The discussion which followed was conducted by the author, the President and Mr. Pemberton. An abstract of the paper will be published in the *Journal* of the Institute.

Mr. Palmer followed with a note on "A Lilac Color from Extract of Chestnut." Mr. Palmer's remarks were as follows:

"In experimenting with a commercial extract of chestnut wood, with the idea of making galloflavine therefrom, an unlooked-for result was obtained. The extract was somewhat fermented; that is, a part of the tannin had been changed into gallic acid; and the design was to convert this gallic acid into galloflavine by the usual method.

"A solution of the 51° extract was made strongly alkaline with potash, and subjected to the action of a stream of air for about ten hours. The temperature, meantime, was kept below 50° F. At the end of the period of oxidation, the potash was neutralized with acetic acid. The solution so obtained was tested for galloflavine by working therein cotton and wool yarns with the addition of potash alum. While no yellow color was obtained, a clear, bright lilac was developed on both the animal and the vegetable fibre.

"The body giving this color has not as yet been separated from the oxidized extract."

The Section then adjourned.

WM. C. DAY, *Secretary.*

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, September 27, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 27, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-eight members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing, which were approved and ordered paid.

Ten nominations to membership were referred to the Committee on Admissions.

Mr. C. W. Pike proposed to amend the first sentence of Article IV of the Section's By-Laws by striking out the words *one dollar* and substituting therefor the words *two dollars*, to make the sentence read, "The annual dues of active, corresponding and associate members shall be two dollars, payable annually in advance, on the first of January of each year." [To be acted on at next meeting.]

Dr. Wm. H. Wahl read a paper describing the plant and process used by the Tacony Metal and Iron Company in electro-plating the large ornamental iron-work for the City Hall, with an aluminum alloy. In discussion thereon, Professor Houston stated that if the plating alloy were electro-negative to iron, the practical success of the operation would be very doubtful.

Prof. Edwin J. Houston read a paper on "Some Curiosities in Early Electro-therapeutics." Referred for publication.

Mr. W. N. Jennings exhibited, by projecting lantern, and described, some photographs of lightning taken by him from a rapidly-moving train on the prairie of North Dakota at midnight, August 8, 1892. The first and second, taken broadside from a car window, showed single and double discharges, and telegraph poles in triple outline. The third, taken from the rear platform of the train, showed a single discharge with buildings in quadruple outline. The fourth showed a wonderful discharge in the form of a broad band which was called "sash lightning." All of the photographs seemed clearly to prove that lightning is an oscillatory motion; Mr. Jennings also showed several photographs of "coronal" electric discharges taken in April, 1889; and outlines of Holtz machine sparks, made directly on photographic plates, without the use of a camera. All of these excited much interest and were discussed at considerable length.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

ON POLYPHASED CURRENTS.

BY PAUL A. N. WINAND.

[*A paper before the Electrical Section, at the stated meetings of April and May, 1892.*]

[*Concluded from p. 330.*]

A MECHANICAL ILLUSTRATION OF POLYPHASED CURRENTS

Before going over to the comparison of the amounts of copper required in line for the transmission of power by means of continuous, alternating and polyphased currents, and to the question of measurement of energy, it may be interesting to describe a simple mechanical model by means of which most of the preceding considerations can be shown in a tangible manner. It consists (*Fig. 11*) in two discs (shown as rings of wire with spokes) mounted in such fashion that they can rock, without being allowed to turn, on their centres. Each disc is provided with a small central shaft perpendicular to its plane. A small crank is so connected to one of the shafts as to impart to it a circular conical motion around the main axis of the apparatus, which is the line joining the centres of the discs. The discs, in order to be prevented from rotating, may be connected to the frame by flat springs, or by strings (as shown), secured to their periphery and to a point of the frame situated at same level as the centre of the disc. When the crank is turned the first disc rocks evenly in all directions, and each of its points has an almost straight up and down motion, which follows the *sine* law very closely; but the different points of the periphery reach their extreme positions successively. Their motions are of different phases.

If strings of equal lengths are stretched from corresponding points of the peripheries from one disc to the other, they will have longitudinal motions following the *sine* law, and will represent the different currents (or electro-motive forces) of a polyphased system.

The second disc, with its shaft, will follow exactly the motions of the first.

Fig. 11 corresponds to a symmetrical five-phase system. Any system, however, can be represented by securing the strings to corresponding points (not only at the periphery) of the discs. The second general condition of polyphased currents is expressed, in the model, by the mechanical analogon: that the centre of gravity of the strings must be on the main axis.

With a slight modification the same model can exhibit the relations between star and mesh currents.

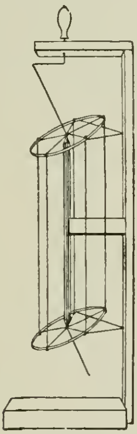


FIG. 11.

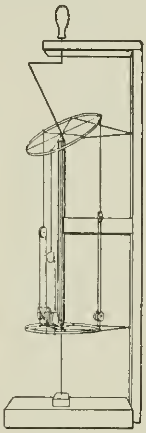


FIG. 12.

Fig. 12 shows this for a symmetrical three-phase. Each string from the first disc carries at its end a small pulley. A continuous string (mesh string) is led over these pulleys and over others fastened to the second disc. If now the axis of the latter be held stationary in the main axis while the crank is being operated, the first named pulleys will move up and down with the star strings, and the mesh string will have a motion of its own, which is different in phase in the different sections of this string, and also different from the motions of the star strings.

In each section the motion corresponds in phase with the current in the corresponding branch of the mesh combination, but its amplitude is double as compared with the motions of the star strings.

EFFICIENCY OF TRANSMISSION AND AMOUNTS OF COPPER.

The comparison in respect to the efficiency of transmission for a given line or to the amounts of copper required for obtaining the same efficiency, has often been made between the alternating and the continuous systems.

We might, therefore, confine ourselves to comparing the plain alternating with the polyphased systems. I will, however, recall concerning the continuous system, that the same current (measured in both cases with a dynamometer) gives the same loss by heating in the same wire whether it be continuous or alternating, as long as the frequency is not so high as to produce an appreciable skin effect.

If the alternations follow the same law for current and potential, and if there is no difference of phase between the two, the rate of flow of energy is the same for continuous and alternating transmission when current and voltage are the same and are both measured with instruments giving readings proportional to the *mean square.*

The same line will then produce equal losses and efficiencies in both cases.

But it should be remembered that, if the *sine* law is followed, when the measured voltages are the same, the *maximum difference of potential* is $\sqrt{2}$ times as large in the alternating than in the continuous transmission. Accordingly it requires twice as much copper to transmit, with the same efficiency, a given energy by alternating than by continuous currents, if the same *maximum* difference of potential is to be allowed in both cases.

It has been claimed by competent men that as far as insulation and danger are concerned, a higher *maximum* difference of potential is allowable on alternating circuits, the more so the higher the frequency. To what extent this is the case appears to be undecided yet, but it seems fair to assume that, for usual frequencies, the *measured* alternating voltage which corresponds to 100 volt continuous is comprised between

$$100 \text{ and } 70{\cdot}7 \left(\text{or } \frac{100}{\sqrt{2}}\right)$$

and that consequently the amount of copper required is larger

for alternating than for continuous transmission, though less than twice as large.

Whatever this proportion may really be, as everything is alternating in the polyphased systems, these doubts do not apply to the comparison between plain alternating and polyphased transmission. A difference of phase between current and electro-motive force, which would necessitate an increased amount of copper in the alternating transmission, would be just as disadvantageous in polyphased currents and would not change the relative values obtained for these two systems.

Everything being alternating, it might seem, at first, that there is no difference in the amounts of copper required for alternating or polyphased transmission with a given efficiency.

In reality, however, the polyphased systems are, gen-

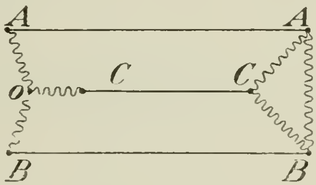


FIG. 13.

erally, more advantageous (the three-phase especially so), and this is due, broadly speaking, to the fact that the voltage on which the energy depends is not always the same as the voltage which has to be considered for insulation.

Fig. 13 represents a symmetrical three-phase, one end being a star, the other a mesh combination. *A-A*, *B-B*, *C-C* are the line conductors If we call V_e the voltage between O and A, and C_l the current (square root of mean square) in AA, we have seen previously that the voltage V_i between A and C for instance is

$$V_i = 1{\cdot}73\ V_e \qquad (1)$$

and the current in AC is

$$C_m = 0{\cdot}577\ C_l$$

It is obvious that the voltage which should be considered

for insulation is V_i, because it is the highest that occurs between any two points of the system.

But the voltage on which the energy depends, together with the current C_1 in the line, is V_e.

The total energy is

$$E_3 = 3\ V_e\ C_1 \tag{2}$$

and if R_3 is the resistance of each line conductor, the total loss in transmission is

$$H_3 = 3\ C_1^2\ R_3 \tag{3}$$

For a plain alternating or two-phase system (*Fig. 14*), the

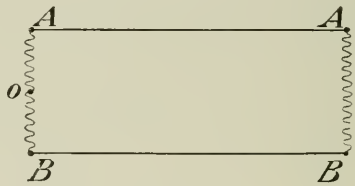


FIG. 14.

voltage $A\ O\ B$ may be designated by 2 V, and there is no distinction to be made for insulation and energy.

$$E_2 = 2\ C\ V \tag{4}$$

$$H_2 = 2\ C^2\ R_2 \tag{5}$$

The alternating and three-phase are of same practical voltage when

$$V = 2\ V \tag{6}$$

Substituting (1) in (6) gives

$$2\ V = 1{\cdot}73\ V_e \tag{7}$$

or

$$V_e = 1{\cdot}154\ V$$

For comparing the cases where the same energy is to be transmitted with the same efficiency, we have to equalize (2) and (4); and this, with (7), gives

$$C = 1{\cdot}73\ C_1 \tag{8}$$

In the line, the currents are 1·73 times as large in alternating than in three-phase.

Equalizing (3) and (5) gives, with (8),

$$R_3 = 2\ R_2$$

This means that the cross section of alternating line conductor is twice that of three-phase conductor, and that the total amounts of copper are as 4 for alternating to 3 for three-phase.

This result, in combination with the erroneous assumption that the alternating system is as advantageous as the continuous, has led to the wrong conclusion that the three-phase is more advantageous (for equal voltage) than the continuous transmission.*

If we compare the cases in which the current density is the same for both, then

$$R_3\ C_1 = R_2\ C$$

and substituting (8) in this

$$R_3 = 1{\cdot}73\ R_2 \tag{9}$$

which, with (3) and (5), gives

$$\frac{H_3}{H_2} = 0{\cdot}866$$

The percentages of loss are as 0·866 in the three-phase to 1 in alternating when the drop of potential along the line is the same.

(9) shows that then the amounts of copper are also as

0·866 to 1

The three-phase is, respecting economy of copper, more advantageous than any other polyphased system.

Whenever the number of phases is *even*, say $2n$, the system can be considered, as far as voltage and energy are concerned, as composed of n distinct ordinary alternating currents, by taking any two diametrically opposite currents together.

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* This comparison relates only to the expenditure of copper for a given voltage, leaving altogether untouched the question of obtaining or dealing more or less easily with high voltages.

The amount of copper needed is, in this case, the same as for plain alternating transmission.

When the number of phases is *uneven* there is a saving in copper, but it is the smaller the higher this number is.

So while it is twenty-five per cent. for the three-phase, it is but 9·5 per cent. for the five-phase, and so on.

The four-phase (often called two-phase) gives no saving over the alternating, as the number of phases is even, when it is used in the symmetrical manner, with four conductors.

When it is worked by means of three conductors (one being a common return, in the well-known manner), the system is unsymmetrical and the amount of copper required is even greater, as will appear from the following:

In *Fig. 15*, *OO* represents the common return wire of such a system.

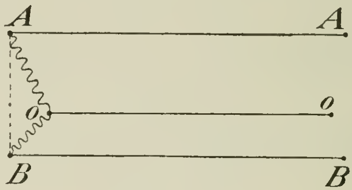

FIG. 15.

Let V_{4e} be the voltage between O and A, and V_{4i} the voltage between A and B, then, as the currents in OA and OB are at

$$90° \text{ or } \frac{\pi}{2}$$

difference of phase and the differences of potential also. This latter, taken between A and B, will differ in phase by

$$\frac{\pi}{4} \text{ and } \frac{3\pi}{4}$$

from those in OA and OB and

$$V_{4i} = 2 \sin \frac{\pi}{4} V_{4e}$$

or

$$V_{4i} = \sqrt{2}\, V_{4e} \tag{10}$$

Correspondingly the currents stand as

$$C_5 = \sqrt{2C_4} \tag{11}$$

if C_4 is the current in AA or BB and C_5 the current in OO. The energy is

$$E_4 = 2 V_{4e} C_4 \tag{12}$$

and the loss

$$H_4 = 2 C_4^2 R_4 + C_5^2 R_5 \tag{13}$$

If we assume the same current density in wires A, B and O, then

$$R_4 = \sqrt{2} R_5$$

which, with (11) and (13), gives

$$H_4 = 2 C_4^2 R_4 + \frac{2}{\sqrt{2}} C_4^2 R_4$$

or

$$H_4 = (2 + \sqrt{2}) C_4^2 R_4 \tag{13a}$$

In order to compare this result with alternating transmission we have to assume

$$V_{4i} = 2 V$$

and equalize (4) and (12), (5) and (13*a*), this, together with (10), gives ultimately

$$R_2 = \frac{2 + \sqrt{2}}{4} R_4$$

The distance of transmission being supposed to be the same, the weight of each conductor is in inverse proportion to its resistance, and the total weights are as

$$8 \text{ to } (2 + \sqrt{2})^2$$

or

$$1 \text{ to } 1{\cdot}457$$

for alternating and four-phase.

As a conclusion of the preceding calculations, if the amount of copper required in the line when the same practical voltage is used and under otherwise identical conditions is 100 for alternating current, it would be 75 for three-phase, 90·5 for five-phase, 70·7 to 100 for continuous, 100 for four-phase when symmetrical, and 145·7 for four-phase with common return wire.

The last named system requires, consequently, almost twice as much copper as the three-phase.

If there is a difference of phase between the currents and potentials, the carrying capacity of the conductors in respect to energy is reduced as the square of the cosine of the difference of phase. But this applies to the alternating as well as to the polyphased systems.

It appears from all the preceding considerations, I think, that the three-phase has decided advantages over the other polyphased and the alternating systems, and I will, therefore, confine my further remarks to the three-phase.

Calculations similar to the above might be carried out for determining the relative losses and the weights of copper in case of a non-symmetrical system. This would, however, be of little practical interest.

MEASUREMENT OF ENERGY.

I shall now touch the question of measurement of energy in the three-phase, but in this respect it is of actual value to consider also the general case of a non-symmetrical system having any differences of phase between the currents and potentials.

When the system is symmetrical the energy is

$$E = 3\ V_e\ C_1 \cos \varphi$$

or

$$E = 3\ V_i\ C_m \cos \varphi$$

In this case, one reading of a dynamometer gives directly the energy, but the instrument cannot generally be connected so as to give one of these results
as

$$V_i = \sqrt{3}\ V_e$$

the energy is also

$$E = \sqrt{3}\ V_i\ C_1 \cos \varphi$$

This formula enables to work with the instrument using the current in the line and the voltage between two line conductors.

As a rule, however, the system cannot be relied upon to be symmetrical.

Messrs. Siemens & Halske have devised a method and constructed an instrument for measuring the energy in this case.*

If the currents in the three line wires are of same magnitude, then by connecting an ordinary dynamometer so that one line current, say in AA, is used, while the volt coil is connected first to A and B, then to A and C, two readings are obtained, whose sum is the total energy.

Their special dynamometer gives this same result in one reading. Its volt coil consists of two separate windings which are connected to A, B and B, C.

If the three voltages, AB, BC and CA, were the same, instead of the three currents, and this is more likely to be the case in practice, the same result would be obtained by a dynamometer provided with a double current coil and a simple volt coil.

Mr. Goerges points out that if the two above-named readings of an ordinary dynamometer are equal, this shows in the present case that there is no difference of phase between current and potential.

He shows further that the energy of any unsymmetrical three-phase can be obtained by six readings on an ordinary dynamometer or by three on the special Siemens instrument.

The above results, as well as a less complicated method, can be established by means of a very simple consideration, which proves useful also in other cases, namely:

> That any three-phase system can always be considered as consisting of two partly superposed independent alternating currents.

One is the current which passes through one line conductor, say AA, and flows back through the two others as a common return.

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* See the paper of Mr. H. Goerges, chief engineer of this firm, in *Elektrotechnische Zeitschrift*, 1891, p. 212.

The second is superposed to the former in the two other conductors and does not affect the current in the first conductor.

Its value is, at any time, half the difference of the currents in B and C, while the value of the first is equal to minus half their sum.

The energy of the first is, at any moment, equal to the product of current A and the mean difference of potential between A on one side and B and C on the other; that is, half the difference of the differences of potential β and γ between $A\ C$ and $A\ B$ when taken with their proper signs.

It is twice this part of the total energy which is measured

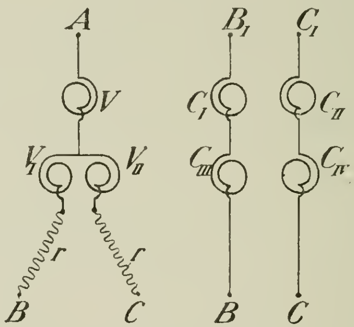

FIG. 16.

by the special Siemens dynamometer when connected as above.

The energy of the second is equal to the product of half the difference of the currents B and C and the difference of potential α between B and C.

The first part of the energy can also be measured by means of an ordinary dynamometer, whose current coil carries the current A while its volt coil is connected to A and to the middle of a resistance stretching from B to C. This resistance need not even be non-inductive, provided its two halves be equivalent.

The second part can be measured by a dynamometer which has a double current coil.

Such an instrument could easily be so arranged as to enable to measure also the first part with a proper change

of connections. The total energy would then be given by two readings.

This result expressed by formulas is

$$E = A\left(\frac{\beta - \gamma}{2}\right) + \left(\frac{C - B}{2}\right)\alpha \qquad (13)$$

which is true as well for the instantaneous values as for their integral or the energy for one unit of time.

It is possible, however, to make an instrument which will combine the actions of these two parts of the energy so as to give directly their sum or the total energy.

Fig. 16 is a diagram showing the working of such an instrument. The part on the left, which may be the movable one, contains one simple volt coil V and a double one,

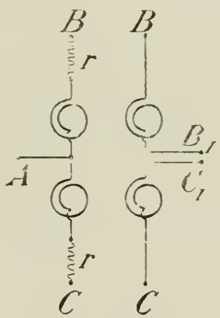

FIG. 17.

$V_{\text{I}}\,V_{\text{II}}$, the two halves of which are wound in opposite directions, and are connected to the equal resistances, r r.

The part on the right contains two double current coils. The halves, $C_{\text{I}}\,C_{\text{II}}$, of the upper one are wound both in the same way and act on coil V only.

The action is proportional at any moment to the sum of the currents B and C, or to current A.

The two halves, $C_{\text{III}}\,C_{\text{IV}}$, of the lower coil, are wound or connected in opposite directions, and act only on coil $V_{\text{I}}\,V_{\text{II}}$.

V_{I} and V_{II} being of opposite directions give no resultant action for the current which flows in V, but their actions are added for the current flowing from B to C through the

resistances r r in consequence of the difference of potential, α.

Dr. H. Aron has devised another method which is simpler yet, as it requires an instrument with four simple coils, acting in pairs, according to the diagram, *Fig. 17*.

He has modified his well-known pendulum watt counter, according to this principle, for use on three-phase circuits.

He has established this principle* by a very simple calculation, which I reproduce below.

If a, b, c represent the instantaneous values of the mesh

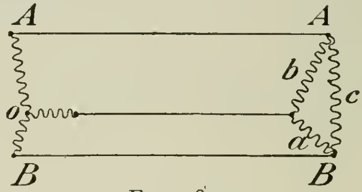

FIG. 18.

currents, *Fig. 18*, and A, B, C; α, β, γ the same as before, then at any moment the total rate of flow of energy is

$$E = a\alpha + b\beta + c\gamma \tag{14}$$

The second condition of polyphased currents (in this case simply Kirchhoff's law) gives for three-phase

$$a - c = B \tag{15}$$

$$b - a = C \tag{16}$$

and the third condition

$$\alpha + \beta + \gamma = O \tag{17}$$

If we subtract the identical expression

$$a(\alpha + \beta + \gamma) = O$$

from (14) we obtain

$$E = \beta(b - a) - \gamma(a - c)$$

which, by substituting (15) and (16), becomes:

$$E = \beta C - \gamma B$$

The two products in this equation represent the instantaneous actions of the two pairs of coils in *Fig. 17*.

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* *Elektrotechnische Zeitschrift*, 1892, p. 193.

It does not seem very natural to substract

$$a(\alpha + \beta + \gamma) = O$$

from (14), but the result can be reached equally well by writing instead of (15) and (16)

$$b = C + a$$

and

$$c = a - B$$

and substituting these values in (14), this gives:

$$E = a\,\alpha + C\,\beta + a\,\beta + a\,\gamma - B\,\gamma$$

$$E = a\,(\alpha + \beta + \gamma) + C\,\beta - B\,\gamma$$

$$E = C\,\beta - B\,\gamma$$

The same result can also be obtained by substituting in the previous equation (13)

$$A = -(C + B)$$

$$\alpha = -(\beta + \gamma)$$

which are but other expressions of the second and third conditions, this gives

$$2\ E = (C + B)\ (\beta - \gamma) + (C - B)\ (\beta + \gamma)$$

$$= C\beta + B\beta + C\beta + C\gamma - B\gamma - C\gamma - B\beta - B\gamma$$

$$2\ E = 2\ C\beta - 2\ B\gamma$$

We see thus that the measurement of energy in the three-phase system, which is likely to be the only one to come into extensive use, can be effected by one single reading of an instrument almost as simple as those used for the same purpose on ordinary alternating circuits.

The result is perfectly accurate and independent of whatever the currents and their phases may be and of however much these may differ from the phases of the electromotive forces.

For that reason the same instruments can be applied to the measurement of energy in the unsymmetrical four-phase, with three conductors (*Fig. 15*), which may be considered as a special case of the general three-phase system.

SOME CURIOSITIES IN EARLY ELECTRO-THERAPEUTICS.

BY PROF. EDWIN J. HOUSTON.

[*Read before the Electrical Section of the Franklin Institute, September 27, 1892.*]

The astonishing physical effects produced by the discharge of the Leyden jar through the human body, led not only the general public, but also the medical fraternity, shortly after its discovery in 1745, to form the most absurd ideas concerning the curative powers of electricity.

The wildest claims were made concerning the efficacy of the electric discharge for the curing of disease. Claims that were at first unhesitatingly accepted as true were soon found in actual practice to fail of realization.

That *bona fide* results in the way of actual cures were obtained in some of the early applications of electricity to the curing of disease appears to be beyond doubt, for the method of treatment in some cases remains practically the same to-day as it was at the time of the discovery of the Leyden jar. Then, again, in those days, as at present, the public's natural credulity led it to perhaps lay more stress on the few cases that were cured than on the more numerous cases that either failed to receive any benefit from the treatment or were actually killed by it; or, putting the same thing in another way, the people who were cured gave glowing certificates of their cures, while the people who were killed gave none.

I have thought that it might interest you if I brought before you a few curiosities in the way of the astonishingly absurd statements that were put forth about the time of the discovery of the Leyden jar, as to the ability of the electric force to cure.

Unfortunately, I have been called upon to read this paper at an extremely short notice, and must, therefore, ask you to take, in many cases, my recollections of matters that I

have read a number of years ago, in place of actual quotations from the original records.

Far be it from my purpose to throw any discredit on the medical fraternity as it existed in the latter part of the eighteenth and the beginning of the nineteenth century, or to throw any doubts on the value of electro-therapeutics as practised at the present day; for the great value to be derived from the intelligent application of electricity for curative purposes is no longer a matter of doubt.

In criticising some of the ideas presented in electro-therapeutics, at the time of the discovery of the Leyden jar, it should be remembered that it is, of course, much easier to find fault with methods than to propose better methods; and when we remember the comparatively limited knowledge the world had acquired concerning the nature of the electric force at these early times, and the belief that was quite common in the scientific world concerning the presence of various effluvia, which were supposed to be capable of passing through the densest matter, we should criticize less harshly some of the beliefs put forward at these early times as to the proper method of applying electricity to the curing of disease. Indeed, an examination of the advertisements of some so-called medical electricians made even in these latter days, would unearth absurdities far more marked than those of the time we are discussing.

I once read in a circular letter issued, if my memory serves me correctly, some fifteen years ago, by a certain so-called medical doctor, in which he claimed among other advantages for the peculiar kind of electricity which he claimed his apparatus was capable of producing, that it was electricity of the corkscrew or gimlet type, and that it, therefore, had but little difficulty in insinuating itself into all parts of the body, so searching out the disease. Or, taking a time not so modern, when a certain inventor, I think, by the name of Edward Craddock Monckton, an exceedingly ingenious man by the way, who has taken out scores of electrical patents, and among others a method of electrically joining articles of jewelry, gravely proposes in

a British patent, to so connect the body of a healthy animal, like a cow for example, with that of the patient to be treated, as to electrically convey the health and strength of the animal to the patient. To do this he places the body of the cow, or other animal, upon an insulating stool, and connecting it to that of the patient to be treated by electric conductors, passes the current of a battery through the animal and subsequently through the body of the patient and thereby, as he claims, conveys to the patient the vitality of the animal.

Passing these aside, however, I would call your attention to a few curiosities in early electro-therapeutics.

It was believed by many of the early practitioners that the virtues of a drug could be readily caused to pass through glass vessels by means of electric discharges. This belief was probably founded on the rather prevalent belief at this time as to the existence of effluvia. The attraction of a magnetic needle by a magnet, notwithstanding the interposition of a plate of glass, was at one time explained on the supposition of effluvia passing out of the magnet and through the glass into the iron. It is not, therefore, surprising to find such statements as that of a Dr. Bruni writing to Dr. Watson of a remarkable case in which, as he claims, medicine shut up in a tightly sealed glass globe produced its peculiar effect on a person who was electrified by the use of said globe. I mention this as a particular case, although the early records of electricity are filled with similar cases. What Dr. Watson has to say about these experiments will, I think, interest you, and I will, therefore, give you the following quotation:

"Dr. Bruni gives me next in his information from Rome, which is, that a gentleman there covered the internal surface of a glass cylinder (which some use instead of a globe) with a purgative medicine; and that man, electrified therewith, found on the spot the same effect as if he had swallowed the medicine. He then recommended to us, in England, to try how far the electric power may be of service in distempers.

"These cases, and particularly the last, as it may to some

appear extravagant and whimsical, I should have been cautious of bringing before the Royal Society, had you not judged it proper they should be added to those similar accounts from other places, which were read to us last meeting. I think neither myself nor Dr. Bruni answerable for the truth of these facts, as we relate no more than we have received. In truth, all the phenomena in electricity are so wonderful that it is scarcely prudent to deny the possibilities of any accounts concerning it till we have made experiments carefully ourselves. We are very sure it is possible to render a living body replete with electrical effluvia, or to transmit and send such effluvia through a living body, in a stream, as long as we think proper: we are not sure that it is impossible for these effluvia to convey with them into that living body the most subtile and active effluvia of other substances; and if they can do so, the effects suggested are not wholly improbable, for several experiments have proved that a very minute quantity of medicine, transfused directly into the blood and circulating fluids, will have the same effect as a large dose thereof taken into the stomach."

Somewhat similar to the effect just referred to was the belief that the odors of certain substances, placed in tightly sealed glass globes, could be detected by sending electric discharges across them; or the similar belief that highly poisonous substances, placed in such glass globes, could produce deleterious effects on people when electric discharges were sent through the glass globes.

In the *Encyclopedia of the Arts and Sciences*, published in 1798, the following account is given of the so-called medicated tubes:

"It was asserted by Signor Pivati at Venice, and after him by Verati at Bologna, Mr. Blanchi at Turin, and Mr. Winkler, at Leipsic, that if odoriferous substances were confined in glass vessels, and the vessels excited, the odors and other medicinal virtues would transpire through the glass, infect the atmosphere of the conductor, and communicate the virtue to all persons in contact with it; also, that those substances, held in the hands of persons electrified, would communicate their virtues to them; so that the

medicine might be made to operate without being taken into the stomach. They even pretended to have wrought many cures by the help of electricity applied in this way. To see the wonderful effects of these medicated tubes, as they were called, Mr. Nollet travelled into Italy, where he visited all the gentlemen who had published any account of these experiments. But tho' he engaged them to repeat their experiments in his presence, and upon himself; and though he made it his business to get all the information he could concerning them, he returned fully convinced, that in no instance had the odors been found to transpire through the pores of excited glass, and that no drugs had ever communicated their virtue to people who had only held them in their hands while they were electrified."

Franklin made a study of the effects of the so-called medicated tubes. In his *Experiments and Discoveries in Electricity*, published in London in 1769, he says on page 82:

"Hence we see the impossibility of success in the experiments proposed, to draw out the effluvial virtues of a non-electric, as cinnamon for instance, and mixing them with the electric fluid, to convey them with that into the body, by including it in the globe, and then applying friction, etc. For though the effluvia of cinnamon and the electric fluid should mix within the globe, they would never come out together through the pores of the glass, and so go to the prime conductor, for the electric fluid itself cannot come through; and the prime conductor is always supplied from the cushion, and that from the floor. And besides, when the globe is filled with cinnamon, or other non-electric, no electric fluid can be obtained from its outer surface, for the reason before mentioned."

In an article entitled "A New Discovery of the Usefulness of Electricity in Medicine," by John Henry Winkler, read before the Royal Society by Mr. Watson, March 31, 1748, and published in abstract on page 399 of Vol. X of the *Philosophical Transactions*, we find the following statement:

"Electricity has a power of dividing subtilely. It carries off with it the parts of those bodies which it dissolves, and transfers them to those parts where the electrical sparks

appear. If odorous substances are ever so closely confined in glass vessels, it so divides them that their exhalations penetrate the glass as easily as magnetical powers, and flow like a river thro' the atmosphere of cylinders and chains, to which the electricity is communicated. The electrical matter which comes out of the extremity of the cylinder, gives an aromatic odor to the hand that touches it. But the odor communicated does not stop in that part of the body on which the electrical river has flowed, but with a continued aspiration pervades the whole human body. Not only the skin and garments are scented, but even the air breathed by the lungs, the spittle, and the sweat of the person affected smell of aromatics, which are agitated by electricity in the closed vessel."

So also the following account of a similar use on page 400 of the same *Transactions* :

"About the beginning of the present year, 1748, I received a letter from Venice, which greatly confirms this conjecture. The author, Joannes Daniel Gaifel, related an affair which surprised all the learned of Venice, Bologna and other cities of Italy. It was accompanied with a printed epistle in Italian, written by an eminent person at Venice, Sig. Jo. Franc. Pivati. In this epistle, the subject of which is medical electricity, he relates a story of wonderful effects to Sig. Fr. Maria Zanotti, Secretary of the Academy at Bologna; and the art, by which these were performed, was the invention of Pivati. A manifest example of the virtue of electricity was shown in the Balsam of Peru, which was so concealed in a glass cylinder, that before the application of electricity there could not be the least smell of it by any means discovered. A man, who having a pain in his side, has applied hyssop to it by the advice of a physician, approached to the cylinder. The man was electrified by it, went home, fell asleep, sweated, and dispersed the power of the balsam. His clothes, bed, chamber, all smelt of it. When he had refreshed himself by this sleep, he combed his head, and found the balsam to have penetrated his hair, so that the very comb was perfumed. The next day S. Pivati electrified a man in health after the same man-

ner, who knew nothing of what had been done before. On his going into company about a quarter of an hour afterwards, he found a gradual warmth diffusing itself through his whole body. He grew lively and more cheerful than usual, His companions were surprised at an odor, and could not imagine whence it proceeded, but he himself perceived that the perfume arose from his own body, at which he was much surprised, not having the least suspicion that it was owing to the operation that had been performed upon him by S. Pivati."

Another equally curious early practice consisted in the use of what might be termed medicated Leyden jars, in which the inner coating of a Leyden jar, through which discharges were given, was formed of or contained liquids, consisting of aqueous solutions of various medical substances. On the discharges from such jars being passed through a patient's body, it was believed that the peculiar effects of the medicine dissolved in the liquid placed inside the jar could be experienced.

Of a similar nature is a rather extended belief which existed at one time as to the effects produced by sending electric discharges through solutions of medicine prior to their being taken into the system,

In a British patent, 991 for 1862, Frederick William Breary describes improvements in medicated cups, which consist practically in sending electric currents through the medicines contained in such cups prior to their being taken into the body. I will quote from the specification of this patent:

"The third improvement of my said invention consists in the formation of similar cups or vessels in and by which the principle of galvanic action is obtained either in combination with the medicinal qualities above mentioned or otherwise. The drinking vessel formed upon this principle I denominate the improved medicated 'galvanic cup.'

"In applying the above-mentioned improvement to my said invention, I make a cup or other suitable vessel (for drinking or other purposes), also in two or more parts, and either form the same on either of the medicated principles

above described, or otherwise, as may be required, and to fix or insert therein a voltaic or galvanic pile, and galvanize or medicate the water or other liquid placed therein by slightly acidulating the same. By preference, however, I form the foot, stem, and outer bowl of these cups or vessels of glass, china, or other non-conducting material; having three or more water tight cells or compartments therein, separated one from the other. I make the centre compartment occupy nearly the whole of the internal space, and make the two side compartments small, but sufficiently large to contain the galvanic media. The latter compartments are closed at the top by means of movable stoppers; the central compartment is made open for containing the medicated water or other liquid to be galvanized. The internal surfaces of the central compartment I line with metal or mineral on one part, and with wood or vegetable, as before described. Extending across this compartment, and forming a metallic connection between the two side cells, I fix a bar or perforated plate of metal. When using this galvanic cup, the water or other liquid is first placed in the centre compartment, where it is medicated; then by filling the side compartments, one with granulated copper and fine sand, and the other with granulated zinc and fine sand, and adding to each a little acidulated liquid, the galvanic essence will pass or flow along and over the metal bar or perforated conductor through the medicated water or liquid, and will impart its medicinal virtues to the same, and thus a combined medicated and galvanized action will be obtained."

BOOK NOTICES.

The Chronicle Fire Tables for 1892. A record of the fire losses of the United States and Territories during 1891, etc. Royal, 8vo, 341 pages. New York: The Chronicle Company, Limited. Price, $5.

These data, now a standard publication, have become exceedingly valuable to underwriters, manufacturers, merchants and others from attention to the details of fire losses, averages, etc., and conscientious exactness in compilation. An idea of the labor expended on this work is obtained from two sentences of the preface: "To procure nearly 40,000 reports of properties burned, to estimate the loss in each case as closely as obtainable data will permit, to place the record of these losses on separate cards, to arrange and rearrange these cards, in order to prepare the various tables which appear on the following pages, is a work of no small proportions." * * * "A search for the exact truth, touching the loss by every fire, is industriously carried on by the publishers of the *Fire Tables*, upon a system which appears to be the best that can be employed."

A list given of the largest fires during 1891, in the United States, shows fifty-one such, ranging in losses from $200,000 to $1,556,948; and there is a comparison of fires of 1890 and 1891 by classes of property, such as dwellings, wholesale and retail stores, manufactories, hotels, theatres, etc., together with percentages of such classes to the whole number of fires. The great tabulation (pages 12 to 32 inclusive) gives with detail every kind of property attacked by fire in 1891, in the United States, with property loss and insurance loss and the causes of fires. If this were the only tabulation in the book it would be well worth the price; but there is much more that is almost equally valuable.

A tabulation extending from pages 34 to 156 inclusive gives the fire losses in each State and Territory by classes of risks, and one (pages 157 to 228 inclusive) shows the fire losses in 1891 by causes. The latter will be most useful to those studying fire insurance data, and to actuaries and statisticians. There is appended a summary of fires from sixty principal causes—including the one great cause "unknown" and the causes "not reported." A part of the mission of this standard publication is to diminish the number of fires in the last two items; in other words, to increase the accuracy of a knowledge of the causes of fires. There are other tabulations in this volume extending over 104 pages, especially one of sixty-six pages, giving monthly losses by States and Territories—and summaries of fires, causes and losses by (in) certain classes of risks. Two illustrative diagrams accompany this portion.

The feelings with which we close this volume are mingled admiration and satisfaction, that such permanent and reliable fire data are collected and published in the United States. We know of nothing equal thereto in Europe. The advantage of the study of such data is to discover, more and more, the

true causes of ignitions, and to apply remedies more intelligently. There has been much progress in this effort during the past decade, in which laudable design for the public benefit the *Chronicle Fire Tables* have materially aided. N.

A Text-Book on Retaining Walls and Masonry Dams. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University. New York: John Wiley & Sons. 1892.

Professor Merriman here presents, in his now well-known concise and scholarly manner, the principles underlying the construction and behavior of walls and dams, or, rather, certain views, more or less widely accepted, respecting those principles; and thus adds still another to the now considerable number of excellent standard works on engineering subjects for which we are indebted to his pen.

With the exception of the theory of the equilibrium of cohesive earth presented in the first chapter, and deduced from the works of continental writers, the present volume makes no pretension to novelty of matter or of treatment. Like the other works of the author, it confines itself chiefly to placing before us, in convenient form, the recognized or accepted laws governing the subjects treated of.

In view of the uncertainty in which the present subject is shrouded (an uncertainty affecting not only the conditions which may obtain in any particular case, but the very foundations of the theories themselves) the average reader may be inclined to wonder at even the moderate display of mathematical pyrotechnics in which our author here indulges; and to ask whether such labors are remunerative, in view of the well-known fact thus stated by the author on pages 52 and 53, respecting that most important factor, the resultant P of the pressures upon the wall:

"Unfortunate, indeed, it is, that the theory of earth pressure is not sufficiently explicit to determine the exact value and direction of P. He who believes the theory of Article 8 must conclude that this wall is in a very dangerous condition, and almost about to slide; he who defends the theory of Article 9 might conclude that it is not in great danger, and that the degree of security is fair. It is well, however, not to forget that the given data are liable to variations fully as serious as the defects in the theory. Imagine a heavy rainfall to increase W and decrease ϕ; this causes P to become larger, and as F usually would be smaller in wet weather it is seen that the degree of stability of the wall will be greatly diminished. If the factor of security be computed for both theories, as is done above, and the variation in the data be regarded, a fair conclusion can generally be made regarding the security of the wall. The effect of the variable data is often so great that a ripe judgment based upon experience may be more reliable than computations."

The work appears to be confined exclusively to the statement and demonstration of the *precepts* pertaining to the subject; and that this has been admirably done the author's name is sufficient guarantee. We fail to notice,

however, a single citation of an *example* from actual practice, a fact which leads us to wonder at the selection of the motto upon the title-page: *In scientiis ediscendis prosunt exempla magis quam præcepta.* T.

Dynamometers and the Measurement of Power. A Treatise on the Construction and Application of Dynamometers; with a Description of the Methods and Apparatus employed in Measuring Water-Power. By John J. Flather, Ph.B., M. M. E. New York: John Wiley & Sons. 1892.

In spite of a somewhat conspicuous absence of that attention to logical sequence in the arrangement of matter, which goes so far to the making of a thoroughly satisfactory introduction to a subject hitherto unknown to the reader, the present little volume will, we think, be found of great use to those desiring to form some acquaintance with the matters here discussed.

After commenting upon the losses entailed by ignorance of the extent to which power is consumed by the various functions of any given set of machinery, and after presenting the fundamental formulas underlying the subject, the author proceeds to a description of known forms of dynamometers, ancient and modern, covering a large number of machines of the various well-known types. In the main these are well and sufficiently illustrated, and (with the reservation already made) satisfactorily explained. Among the forms described, those of our late member, Mr. Robert Briggs, and of our ex-President, Mr. Wm. P. Tatham, are of course not overlooked, while a hydraulic dynamometer designed by the author is modestly placed at the end of the list.

A short chapter is devoted to the power required for driving lathes, showing that this power varies considerably more than is popularly supposed, and the volume concludes with a résumé of the methods in use for the measurement of flowing water and of contrivances specially adapted to the testing of hydraulic motors.

The index is perhaps ample for a work which, like this, treats of a single subject. T.

Johnson's Tables. Stadia and Earth-work Tables. Four-plate Logarithms. Logarithmic Traverse Table, Natural Functions, Map Projections, etc. Re-printed from Theory and Practice of Surveying. By J. B. Johnson, Professor of Civil Engineering, Washington University, St. Louis. New York: John Wiley & Sons. 1892.

As indicated by the title, this is a reprint from the author's standard work on surveying which has already been noticed at length in these pages, and the tables are chiefly counterparts of those in common use. Hence no extended review is called for at this time. We are glad to note a decided improvement, as compared with the larger work, in the important particulars of paper and press-work, in spite of which, however, much of the work, and notably the two-page table of four-place logarithms, from Lee's *Tables and Formulæ*, fails of distinction for typographical excellence. T.

Franklin Institute

[*Proceedings of the stated meeting, held Wednesday, October 19, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 19, 1892.

MR. HENRY R. HEYL, in the chair.

Present, 190 members and twenty-two visitors.

Additions to membership since last report, five.

The Secretary reported the resignation, from the Committee on Science and the Arts, of Dr. George A. Koenig. An election was ordered to fill the vacancy.

Mr. Shaw nominated Mr. F. M. Jacquith; Prof. Rondinella nominated Mr. F. Lynwood Garrison. Mr. Garrison received forty-two votes, and Mr. Jacquith twelve. Mr. Garrison was accordingly declared elected.

Mr. F. E. Ives read a paper descriptive of the principles of construction and operation of the heliochromoscope, a new optical instrument of his invention for the reproduction of natural colors in photography. The speaker at the close of the meeting exhibited a photograph of a bouquet of natural flowers in the apparatus, by means of which the natural colors of the objects were very faithfully reproduced. Mr. Ives' paper was discussed by Messrs. Goldschmidt, Fullerton, Cooper and the Secretary. The paper was referred for publication.

Mr. S. Y. Buckman described an automatic tin-plate machine of his invention, and in connection therewith gave a sketch of the present state of the art of making tin plates. The machine of Mr. Buckman takes the pickled sheets (which are longer than those used in the usual method of hand-dipping), and successively and continuously performs the operations of scouring, drying, joining, fluxing and coating, and turns out the product in a continuous strip of terne plate of any desired length. (Referred for publication.)

Mr. W. E. Lockwood described the Boyer Railway Speed Recorder, and an Improved Smoke and Spark-consuming Device in Locomotive Practice.

The Secretary in his monthly report referred to the present condition of the Nicaragua Canal enterprise, and presented an abstract of the proceedings of the recent National Nicaragua Canal Convention, held at St. Louis, in which the project was cordially endorsed.

Mr. Shaw moved that the President be empowered to appoint a committee of three to confer with a similar committee to be named by the Manufacturers' Club, with the object of preparing a statement embodying the views of the two bodies for transmission to the Department of State. Carried.

Adjourned. WM. H. WAHL, *Secretary.*

JOURNAL

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OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIV. DECEMBER, 1892. No. 6

HOW THE EARTH IS MEASURED.*

BY PROF. J. HOWARD GORE.

[*A lecture delivered before the Franklin Institute, November 30, 1891.*]

[*Concluded from p. 366.*]

The name which will always be associated with the early history of Geodesy is that of Willebrord Snell (or Snellius), a Netherland geometer. He has rendered the first years of the seventeenth century luminous by the brilliancy of his mathematical conceptions and the boldness with which he followed up his hypotheses. To him belongs the credit of having first promulgated the theory of the refraction of light and the discovery of the three-point problem, usually ascribed to Pothenot, while he enriched the literature of astronomy by the publication of an important paper on comets.

* Certain portions of this paper are taken from the author's work on *Geodesy*, published by Houghton, Mifflin & Co.

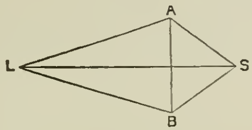
The year 1615 carries with itself the glory of having witnessed the inception of that method which will always be used in geodetic determinations—that is, the system of triangulating from a known base, in this way reducing the probability of error in its greatest source—the measurement of a long line.

As this general plan has been followed by all who have subsequently made attempts to determine the length of a terrestrial arc, the method of Snell deserves a complete description.

It is said that Ptolemy pointed out the fact that in order to determine the length of an arc it was not necessary to measure along a meridian. Still no one was willing to accept this belief until Snell demonstrated it to be true. He went still further, saying that since it is not essential to measure on a meridian, it is not absolutely necessary that the terminal points should be connected by a straight line, but the line may be broken. This, perhaps, suggested at once that at least some of the lines might have their lengths computed, thereby saving the trouble of measuring them. It was, of course, known at that time that in a triangle, if one side and the angles be given the remaining sides can be found. The known side might be short, while the computed sides could be relatively much longer. From this it was but a step to realize that a side which has been computed in one triangle may become the known side in an adjoining triangle and aid in determining the remaining sides of the latter. Thus, triangle could be joined to triangle link by link—forming what is now called a chain or net—with only one side, called the *base*, determined by direct measurement.

His operations stretched over the arc between Alcmaar and Bergen op Zoom, and was computed in the following manner: He measured with a chain a base that was perpendicular to the line joining Leyden and Soerterwoude, $A\ B$ in the appended figure; this was 326·4 Rhenish rods. With this line known and all the angles of the triangles $L\ A\ B$, $A\ B\ S$, and $L\ A\ S$, he computed $L\ A$ as a side of the first-named triangle and $A\ S$ a side of the second; then

with *L A*, *A S*, and the angle *L A S* known, the side *L S* was computed, giving this as a new base. Upon this he formed a new triangle, and continued so doing until he had

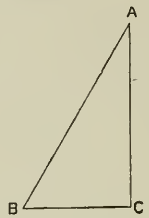


a chain of thirty-three triangles reaching a church spire which he had previously selected for the terminal point.

The angles were measured with a graduated semicircle of three and one-half feet diameter. This size was necessary as it was not until sixteen years later that the vernier was introduced to aid in reading angles. This semicircle was likewise unprovided with telescopes, so that the observer had to rely on the unaided eye in sighting to distant objects. Snell realized that this crude method was liable to introduce uncertainties, so he sought to reduce them to a minimum by measuring all the angles of each triangle and computing each side through different routes. As these variously obtained values were in all cases quite harmonious, he naturally congratulated himself upon the attainment of correct results.

Now, knowing the length of each side, the summation of a set of contiguous lines gave the length of the *broken* line joining his terminal points. However, these lines not having the same direction it was necessary to calculate what the length of each line would be if it had the direction of the line joining the ends of his arc; that is, he found the *projection* of each line upon this direction; then the sum of these projections gave the distance required, which he found to be 34710·06 rods. With this value for *A B* it was necessary to find *A C*, the meridian distance between *A*, Alcmaar, and *C* the parallel of *B*, Bergen op Zoom. Here again the question was simply to find the projection of *A B* on a north and south line. For this he needed to know in addition to *A B*, the angle *B A C*, or the *azimuth* of the oblique arc *A B*. For the purpose of determining this azimuth, Snell carefully fixed from astronomic observations

the meridian of Leyden, and then measured at Leyden, the angle which one of the sides in his chain made with this meridian. By combining this azimuth, or angle of position



as he called it, with certain angles in the chain, he obtained the azimuth of *A B* or the angle *B A C*. The result of this computation gave 33,930 rods for *A C*.

With the length of the arc known, nothing remained but to know its amplitude, or the difference in the latitude of Alcmaar and Bergen op Zoom. The latitudes were determined from observations made with a quadrant of five and one-half feet diameter, likewise without a telescope. The results of his observations gave:

Latitude Alcmaar, ...	52°	40′	30″
Bergen, ...	51°	29′	00″
Amplitude of the arc, ...	1°	11′	30″

So we have for a degree $\frac{60}{71.5} \cdot 33930$ or 28,473 rods. By taking the arc from Leyden to Alcmaar he found for a degree 28,510 rods; from these two discordant results he arbitrarily assumes 28,500 rods for a degree.

As most of the measures of this period are given in toises (a toise being approximately 6·4 feet), the length of a degree as given by Snell is 55,072 toises, counting the rod at 1·9324 toises.

Since the error in this length of a degree is practically 2,000 toises, while the method is, in general terms, correct, it is well to look into the sources of this discrepancy. The first which attracts our attention is the fact that he regarded the surface of the earth as a plane, and computed all of his triangles by plane instead of spherical trigonometry, without making any correction for *spherical excess*—the amount

by which the three angles of a spherical triangle exceed 180°. This negligence, however, would introduce no serious error, as none of the triangles were large, and the spherical excess is only about one second for seventy-five square miles. But in the last triangle *B A C* when computing the length of the *arc A C*, Snell regarded it as a *chord*, thereby making an error of one toise.

Had his vertices or stations been at different elevations it would be necessary to reduce the angle which he observed between two stations of different elevations to its equivalent in the plane of either, because his instrument was not level, but so canted as to be in the oblique plane of the two stations—so that the angle read was oblique and not horizontal. The modern method of observing with the circle level provided with a telescope having a vertical motion enables one to ascertain at once the horizontal angle between points of different elevations. Then we project all vertices upon the surface of an ellipsoid which differs the least possible from the mathematical shape of the earth and bind these points with lines upon this surface. After deducting equally from each angle the computed spherical excess, the computations are carried forward in accordance with the established principles of plane trigonometry.

Thus far the sources of error pointed out in this pioneer work are insignificant. Those that remain are: base-measuring, angle-reading and astronomic determinations.

Snell himself suspected the existence of the two first named and went so far as to re-measure his base, which he did with wooden rods on the ice which was formed on the overflowing waters around Leyden in 1622. A triple measurement of this base satisfied him that his linear determination was good. He then repeated the measurement of the angles and found some discrepancies which caused him to say in his note-book that his last readings were the only reliable ones. By this time his advanced age prevented him from recomputing all the triangles—a labor at that time very onerous, owing to the non-existence of logarithmic tables.

About 100 years later Musschenbroek, a descendant of

Snell, revised the entire work, using a quadrant with a telescope attached. With this instrument he detected a number of errors in the angles of his predecessor, which, with a new determination of the latitudes of the terminal points, gave a value very nearly correct, according to our present judgment.

Modern practice differs from Snell's operations in character rather than kind. We measure now a short line three or four miles in length, erect upon it sides of a triangle, add triangle to triangle, forming a chain, project the continuous broken line upon a meridian, determine the amplitude of the arc by obtaining the latitudes of its termini and thus find the length of a degree.

But in measuring the base we exercise the greatest caution, in obtaining the exact length of the measuring unit in terms of a standard, and in securing conditions such as insure exact repetitions of this unit. So that when we say the base contains the unit a certain number of times, we know that the length will be expressed by that number of times a known quantity. Those who have had experience with instruments of precision know how difficult it is to obtain the length of one unit in terms of another; and all who have employed standards of measure, or sought constant temperature will realize how hard it is to repeat operations under similar conditions. Notwithstanding these difficulties great accuracy is possible. Last summer it was my good fortune to participate in the measuring of a base. We obtained two results for its length, differing from one another by a quantity less than one-fifth of an inch—a discrepancy remarkably small when we consider that the length of this base was more than three miles.

In the matter of triangulation improved angle-reading instruments are now employed, and extra precautions are taken to observe under such conditions as to eliminate errors of refraction, or errors resulting from faulty construction of the instrument. That this has been successfully accomplished can be seen from the statement that the measured length of the Olney base differed from the value obtained through triangulation from the Chicago base—200

miles distant—by *two* inches—and this achievement does not stand alone.

The astronomic determinations—one of the most important features—have likewise improved in accuracy, and calling electricity to their aid, astronomers are now enabled to ascertain with requisite precision the amplitude of an arc of parallel by determining the difference of longitude of the terminal points.

In this advance there was demonstrated beyond doubt the fact that a degree of the equator had not the same length that a degree of meridian had. This had been suspected long before astronomy gave the casting vote, and as if to complicate the problem degrees of the same meridian seemed to have lengths varying with the latitude. Theory and pure mathematics in the wizard hands of Newton made ellipses of the earth's meridians—ellipses whose shorter axis was the axis of rotation. At the poles, therefore, the curvature, the amount of change or deflection from a straight line was less than at the equator, and as a greater circumference and hence longer degree go with the less curvature, a degree near the pole would be longer than towards the equator.

Inseparably connected with the name of Newton is that of Huygens. His attention was first drawn to the subject of the figure of the earth by the variation in the length of the seconds pendulum in different latitudes, which was first announced as an observed fact when Richer returned in 1672 from Cayenne. It was quite natural that Huygens should take notice of everything related to pendulum behavior, as he was at this time busy with the application of the pendulum to the regulating of clocks. He immediately perceived that this phenomenon—the shortening of the seconds pendulum on approaching the equator—was caused by the centrifugal force at the earth's surface, which, increasing as the equator is approached, lessens the power of gravity and retards the time of the pendulum's vibration. It also occurred to him that if the earth were a perfect sphere, a plumb-line would not be at right angles to the sea, or to the surface of standing water, but would be

deflected somewhat by the action of centrifugal force. Hence a light body in still water would not press perpendicularly upon the surface, and consequently could not be at rest, which is contrary to experience. Huygens, therefore, argued that the earth was not spherical, but protuberant at the equator, so that the terrestrial meridians might everywhere be perpendicular to the plumb-line. Here he ceased speculating, perhaps waiting for observations to in some way substantiate his views, nor did he proceed until Newton furnished the stimulus in the nature of a suggestion.

Newton determined the ratio of the two axes by conceiving two columns of fluid to extend from the centre of the earth outward towards the surface; one to the equator, the other to one of the poles. Since these two columns were in equilibrium they would press upon one another with equal intensity, so that the ratio of their lengths would be found by comparing their weights. The weight of the equatorial column is equal to gravitation diminished by centrifugal force, while the polar column, unaffected by the earth's diurnal motion, had a weight dependent solely on the gravitation of its particles.

This centrifugal force of each equatorial particle depended upon its angular velocity and its distance from the centre, but its gravitation, resulting from the combined attraction of the surrounding particles, was one of the problems first solved by Newton. The result of this discussion gave as the ratio of the polar to the equatorial axis, 229 to 230. This is usually stated $b : a :: 229 : 230$, and the ellipticity, which is the ratio of $a - b$ to a is $\frac{1}{230}$.

This was the needful suggestion for Huygens. He at once took up the problem, but rejecting the Newtonian principle of an attraction between the particles, he placed in the centre of the mass a force attracting the particles according to the inverse square of the distances. Upon this hypothesis he proved that a homogeneous body of fluid revolving upon an axis will be in equilibrium when it has the figure of an oblate spheroid very little different from a sphere, the ellipticity being one-half of the ratio of centrifugal force to the gravity at the equator, or $\frac{1}{2} \times \frac{1}{289} = \frac{1}{578}$.

He tried to verify his theory from actual experiment, so he took a soft globe of clay and attached it to an axis. This he caused to revolve very rapidly, when he observed that the ball became flattened at each end of the axis and enlarged at the middle.

He very cleverly concluded from this theory that the water adjusts itself over the surface of the earth and that the fixed land must do the same—for if the land at the poles were exactly at the same distance from the centre of the earth that the equator is, the water of the sea in this latter region would be raised above the land. But since we find at the equator large areas of land, these too must have been thrown out under the action of centrifugal force, and for this to be possible, the earth was at one time in a fluid condition, becoming solid later in its life. Quite recently Professor Stokes has enunciated almost the same idea when he said that the fact that the waters of the earth are in equilibrium shows that at some time there must have been a bulging out of the land in the equatorial regions. Newton saw in the flattening of Jupiter as reported by Cassini (1691) a proof by analogy of the oblate hypothesis.

The acceptance of a flattened earth was by no means instantaneous. Terrestrial measures were not harmonious, but their weight of evidence was on the other side or towards an elongated earth. This caused a conflict—notable in the history of Geodesy sending champions of the latter hypothesis to Peru and within the polar circle to bring back as the fruits of years of toil the lengths of an equatorial degree and of a polar degree. The evidence was on the unexpected side—the earth was flattened. However, the adherents did not at once relinquish the elongated theory, but computed and re-computed the tell-tale figures, discussed and re-discussed the methods which yielded such unwelcome results.

Knowing that the earth is round like an orange and flattened at each pole is not sufficient, the amount of this flattening is of great importance—it enters as a potent factor into all computations of directions and distances which extend over any considerable portion of the earth's surface.

With an erroneous value for this flattening—this ellipticity—maps would be a contorted representation of countries, boundary lines would cause endless confusion and ships often follow a plotted course to their destruction.

The earth's diameter is often the astronomer's unit, and furnishes him with a base on which to construct triangles to bring the starry bodies under our grasping measures. A faulty value for this unit retarded for twenty years the discovery of the theory of universal gravitation, and with its correction that principle—finite in demonstration was applied to the infinite and worlds were harnessed with invisible traces.

To know the length of degree, to ascertain the shape of the earth, men have braved the cold within the Arctic circle, endured the heat of the equatorial regions, and penetrated India's malarial jungles. Peaks have been climbed, deserts traversed, and hostile tribes subjugated. To the theoretical side scores of the world's most profound mathematicians have devoted their time, contributing 6,000 treatises to the literature of the subject, while the practical side has been pushed ahead by the energies of countless troops of observers, artisans and laborers, supported by the expenditure of millions upon millions of dollars, and is advanced at this time by the united efforts of sixteen nations, each working within its own territory, but with a common plan and harmonious methods.

Does our utilitarian friend listen patiently and say despondingly *cui bono?* One item of ignorance dispelled is like a grain of sand removed from the most delicate mechanism. One particle of knowledge diffused is a lubricant that may facilitate the movements in the vast cycle of sciences from centre to periphery.

The line joining two points of observation on the earth's surface is our base line for estimating the distance to the heavenly bodies. With an approximately correct value for this Newton demonstrated a principle as unlimited as the infinite. What a more accurate value may suggest is beyond conjecture.

He who makes a contribution to science benefits the

human race. He furnishes a stimulus whose action is above conception, and plants a seed whose fruit may nourish coming ages.

Morse invented the telegraph but had to wait for Henry's induction coil. The telephone was a useless toy in Germany until Bell made electricity the vibrating agent. Adams saw Neptune in the perturbations of Uranus before it was visible to Galle's cyclopian eye. Mendalaef pointed out by a Keplerian law three chemical elements when the catalogue was supposed complete.

Instances without number might be given showing how the world stood still awaiting a scientific discovery, how practice paused for theory, how the artisan's hand was freed by a savant's brain.

We do not glorify the Arctic explorer simply because he waved our flag over a parallel never before visited, but because of the direct visible result of the spirit of investigation, and the indirect encouragement for others to search more prolific fields.

The African traveller returning with the map extended over much that was hitherto unknown ground makes as his greatest contribution, the inspiration to observe what surrounds us, to widen our limits, and "to see books in running brooks."

The link binding animal to vegetable life may be verified by a fisherman finding a more simple example of sporadic existence. The earliest stage of life on this globe may be pushed down below the geologist's calendar by a child picking up a single fossil.

Let us then honor science for science sake as well as for its utilitarian results. Let us revere that motive which prompts men to measure the earth with a span or estimate the approach of a star by a spectroscopic line.

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

BY EMRICK A. WERNER.

[*Continued from p. 384.*]

MAXIMA.

C_{15} *maximum.* Maximum line $g_m = \frac{1{,}500}{65} = 23{\cdot}1$

$$\text{Maximum span} = (g_m - a) + a = 23{\cdot}1$$

$$\frac{dC}{dg}\, max = 20\ W_1 - 13\ W$$

Second driver of first engine in (15); fifth driver 2·25 from Abutment A.

To the right of the dividing line (15)

$$W = 140 \quad W_1 = 100$$

To the left of the dividing line (15)

$$W = 140 \quad W_1 = 75$$

whence

$$\frac{dC}{dg} = \begin{cases} 1{,}820 - 2{,}000 < 0 \\ 1{,}820 - 1{,}500 > 0 \end{cases}$$

and

$$R\ l = 19{,}248$$

$$R'\ l = 1{,}752$$

$$\text{Check } R\ l + R'\ l = 21{,}000 = 140 \times 150 = W\ l$$

$$R_{15} = 638$$

$$R_{75} = 8{,}748$$

$$H\ f = R\ \frac{l}{2} - R_{75} = 876$$

$$H\ y = H\ f \,.\, \frac{y}{f} = 315$$

$$\text{Check } R'_{15} = 290$$

$$R'_{75} = 20$$

$$H'\ f = \frac{R'\ l}{2} - R'_{75} = 9{,}624$$

$$Hf \div f = H = 29{,}200$$

$$C_{15}\ max. = \left(\frac{M}{h}\right)_{15} - H = 972 \div 22{\cdot}2 - H = 43{,}800 - 29{,}200 =$$

$$= +\ 14{,}600$$

$$\text{Check}\ \left(\frac{M}{h}\right)' - H = +\ 14{,}600$$

$$D_{\mathrm{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{0} = +\ 43{,}800$$

C_{30} *max.*—

$$\text{Maximum span} = 40{\cdot}0$$

$$\frac{dC}{dg} = 4\ W_1 - 3\ W$$

Second driver in point (30), second tender wheel 5·75 from Abutment A.

$$H = 69{,}200\ \left(\frac{M}{h}\right)_{15} = 1{,}702 \div 22{\cdot}2 = 123{,}400$$

$$C_{30}\ max. = \left(\frac{M}{h}\right)_{15} - H = +\ 54{,}200$$

$$D_{\mathrm{II}} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = +\ 67{,}700$$

C *max.*—

$$\text{Maximum span} = 53{\cdot}0$$

$$\frac{dC}{dg} = 20\ W_1 - 17\ W$$

First driver on point (45), last wheel of first tender 6·0 from Abutment A, followed by 3·8 feet of 3,000 pounds per lineal foot.

$$C_{45}\ max. = \left(\frac{M}{h}\right)_{45} - H = 1{,}682 \div 78 - H = 108{,}300$$

$$D_{\mathrm{III}} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = +\ 79{,}300$$

C_{60} *max.*—

$$\text{Maximum span} = 63{\cdot}2$$

$$\frac{dC}{dg} = 20\ W_1 - 19\ W$$

First wheel of first engine in (60), last wheel of tender 13·0 from Abutment A, followed by 10·8 feet of 3,000 pounds per lineal foot.

$$C_{60}\ max. = 976 \div 42 - H = 232{,}200 - 135{,}600 = 96{,}600$$

$$D_{\mathrm{IV}} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = +\ 200. -$$

Minima.—

C_{15} *min.*—

Minimum span = 126·9

$$\frac{dC}{dg} = 13\ W - 22\ W_3$$

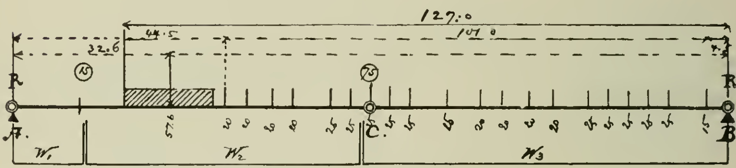


FIG. 17.

$$C_{15}\ min. = -H + \left(\frac{M}{h}\right)_{15} = -\ (364{,}400 + 37{,}100) =$$

$$= -\ 401{,}500 \text{ pounds.}$$

$$D_{\mathrm{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{0} = -\ 37{,}100 \text{ pounds.}$$

C_{30} *min.*—

Minimum span = 110′·0

$$\frac{dC}{dg} = 15\ W - 22\ W_3$$

Third driver of second engine on top hinge.

$$C_{30}\ min. = -\ 443{,}700$$

$$D_{\mathrm{II}} = -\ 58{,}200$$

C_{45} *min.*—

Minimum span = 97·0

$$\frac{dC}{dg} = 17\ W - 22\ W_3$$

Fourth driver of first engine on top hinge.

$$C_{45}\ min. = -\ 503{,}600$$

$$D_{III} = -\ 74{,}900$$

C_{60} *min.*—

$$\text{Minimum span} = 86{\cdot}8$$

$$\frac{d\,C}{d\,g} = 19\ W - 22\ W_3$$

Second driver of first engine on top hinge.

$$C_{60}\ min. = -\ 515{,}500$$

$$D_{IV} = -\ 25{,}500.\text{—}$$

Horizontal Component D of the Stresses in the Diagonals—

$$D_x = C_x - C_{x-\Delta x} = \Delta\, C_x = \left(\frac{M}{h}\right)_x - \left(\frac{M}{h}\right)_{x-\Delta x}$$

Using the bottom chord, we have:

$$D_I = C_{15} - C_0$$

but

$$C_0 = \left(\frac{M}{h}\right)_0 - H = -\ H$$

hence:

$$C_{15} = [0{\cdot}35\ W_1\,g_1 + W_2\,(15 - 0{\cdot}65\ g_2) - 0{\cdot}45\ W_3\,g_3]\ \frac{1}{22{\cdot}2}$$

$$\text{subtracting } 22{\cdot}2\ H = [0{\cdot}37\ W_1\,g_1 + W_2\,(o + 0{\cdot}37\ g_2) +$$

$$+\ 0{\cdot}37\ W_3\,g_3]\ \frac{1}{22{\cdot}2}$$

$$D_I = [0{\cdot}72\ W_1\,g_1 + W_2\,(15 - 0{\cdot}28\ g_2) - 0{\cdot}08\ W_3\,g_3]\ \frac{1}{22{\cdot}2}$$

$$D_{II} = C_{30} - C_{15} = \Delta\ C_{30}$$

$$22{\cdot}2\ C_{30} = [5{\cdot}55\ W_1\,g_1 + W_2\,(666{\cdot}0 - 16{\cdot}65\ g_2) -$$

$$-\ 7{\cdot}77\ W_3\,g_3]\ \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$

$$\text{subtracting } 13{\cdot}8\ C_{15} = [4{\cdot}83\ W_1\,g_1 + W_2\,(207{\cdot}0 - 8{\cdot}97\ g_2) -$$

$$-\ 6{\cdot}21\ W_3\,g_3]\ \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$

$$D_{II} = [0{\cdot}72\ W_1 g_1 + W_2(149{\cdot}0 - 7{\cdot}68\ g_2) -$$
$$- 1{\cdot}56\ W_3 g_3] \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$
$$D_{III} = C_{45} - C_{30} = \Delta C_{45}$$
$$13{\cdot}8\ C_{45} = [2{\cdot}07\ W_1 g_1 + W_2(621{\cdot}0 - 11{\cdot}73\ g_2) -$$
$$- 3{\cdot}45\ W_3 g_3] \frac{1}{13{\cdot}8 \times 7{\cdot}8}$$
subtracting $7{\cdot}8\ C_{30} = [1{\cdot}95\ W_1 g_1 + W_2(234{\cdot}0 - 5{\cdot}85\ g_2) -$
$$- 2{\cdot}73\ W_3 g_3] \frac{1}{13{\cdot}8 \times 7{\cdot}8}$$

$$D_{III} = [0{\cdot}12\ W_1 g_1 + W_2(387{\cdot}0 - 5{\cdot}88\ g_2) -$$
$$- 0{\cdot}72\ W_3 g_3] \frac{1}{13{\cdot}8 \times 7{\cdot}8}$$
$$D_{IV} = C_{60} - C_{45} = \Delta C_{60}$$
$$7{\cdot}8\ C_{60} = [0{\cdot}39\ W_1 g_1 + W_2(468{\cdot}0 - 7{\cdot}41\ g_2) -$$
$$- 1{\cdot}17\ W_3 g_3] \frac{1}{7{\cdot}8 \times 4{\cdot}2}$$
subtracting $4{\cdot}2\ C_{45} = [0{\cdot}63\ W_1 g_1 + W_2(189{\cdot}0 - 3{\cdot}57\ g_2) -$
$$- 1{\cdot}05\ W_3 g_3] \frac{1}{7{\cdot}8 \times 4{\cdot}2}$$

$$D_{IV} = [-0{\cdot}24\ W_1 g_1 + W_2(279{\cdot}0 - 3{\cdot}84\ g_2) -$$
$$- 0{\cdot}12\ W_3 g_3] \frac{1}{7{\cdot}8 \times 4{\cdot}2}$$
$$D_V = C_{75} - C_{60} = \Delta C_{75} = \left(\frac{M}{h}\right)_{75} - H - C_{60} =$$
$$= -[H + C_{60}]$$
$$C_{60} = [0{\cdot}05\ W_1 g_1 + W_2(60{\cdot}0 - 0{\cdot}95\ g_2) - 0{\cdot}15\ W_3 g_3] \frac{1}{4{\cdot}2}$$
adding $4{\cdot}2\ H = [0{\cdot}07\ W_1 g_1 + W_2(o + 0{\cdot}07\ g_2) + 0{\cdot}07\ W_3 g_3] \frac{1}{4{\cdot}2}$

$$D_V = -[0{\cdot}12\ W_1 g_1 + W_2(60 - 0{\cdot}88\ g_2) - 0{\cdot}08\ W_3 g_3] \frac{1}{4{\cdot}2}$$

Check:

Using the top chord we find:

$$D_{\mathrm{I}} = C_{15} - C_0 = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_0 = \left(\frac{M}{h}\right)_{15}$$

$$D_{\mathrm{I}} = [0{\cdot}72\ W_1 g_1 + W_2 (15 - 0{\cdot}28\ g_2) - 0{\cdot}88\ H_3 g_3]\ \frac{1}{22{\cdot}2}$$

$$D_{\mathrm{I}} = C_{30} - C_{15}$$

$$22{\cdot}2\ C_{30} = [10{\cdot}656\ W_1 g_1 + W_2 (666{\cdot}0 - 11{\cdot}544\ g_2) -$$

$$- 2{\cdot}064\ W_3 g_3]\ \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$

subtracting $13{\cdot}8\ C_{15} = [9{\cdot}936\ W_1 g_1 + W_2 (207{\cdot}0 - 3{\cdot}864\ g_2) -$

$$- 1{\cdot}104\ W_3 g_3]\ \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$

$$D_{\mathrm{II}} = [0{\cdot}72\ W_1 g_1 + W_2 (459{\cdot}0 - 7{\cdot}68\ g_2) -$$

$$- 1{\cdot}56\ W_3 g_3]\ \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$

$$D_{\mathrm{III}} = C_{45} - C_{30} = [18{\cdot}3\ C_{45} - 7{\cdot}8\ C_{30}]\ \frac{1}{13{\cdot}8 \times 7{\cdot}8} =$$

$$= [0{\cdot}12\ W_1 g_1 + W_2 (387{\cdot}0 - 5{\cdot}88\ g_2) -$$

$$- 0{\cdot}72\ W_3 g_3]\ \frac{1}{13{\cdot}8 \times 7{\cdot}8}$$

$$D_{\mathrm{IV}} = C_{60} - C_{45} = [7{\cdot}8\ C_{60} - 4{\cdot}2\ C_{45}]\ \frac{1}{7{\cdot}8 \times 4{\cdot}2} =$$

$$= [- 0{\cdot}24\ W_1 g_1 + W_2 (279{\cdot}0 - 3{\cdot}84\ g_2) -$$

$$- 0{\cdot}12\ W_3 g_3]\ \frac{1}{7{\cdot}8 \times 4{\cdot}2}$$

$$D_{\mathrm{V}} = C_{75} - C_{60} = - C_{60} = - [0{\cdot}12\ W_1 g_1 + W_2 (60 - 0{\cdot}88\ g_2) -$$

$$- 0{\cdot}08\ W_3 g_3]\ \frac{1}{4{\cdot}2}$$

Maxima:

$$D_{\mathrm{I}} = C_{15}\ max. = \left(\frac{M}{h}\right)_{15} max. = 62{,}600 \text{ pounds.}$$

$$D_{\mathrm{II}}\ max. \text{— Max. line — } g_m = \frac{45{,}900}{768} = 59{\cdot}64 \text{ from } b = 0$$

$$\text{Max. span} = a + (g_2 - a) = 59{\cdot}64$$

$$\frac{dD}{dg} = -\alpha\,(W_1 + w) + \beta\, W_2 + \frac{w}{\Delta x}\,[\alpha\, x - (k - \beta\, x)] =$$

$$= -0{\cdot}72\,(W_1 + w) + 7{\cdot}68\ W_2 - 207\ \frac{w}{15}$$

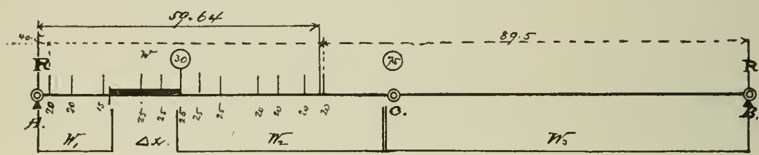


FIG. 18.

To the right of the dividing line (15)

$$[W_1 = 55\ w = 75]\ W_2 = 130$$

To the left of the dividing line (15)

$$[W_1 = 55\ w = 50]\ W_2 = 155$$

whence

$$\frac{dD}{dg} = \left|\begin{array}{l} -75{\cdot}6 + 1190{\cdot}0 - \ \ 690{\cdot}0 = -\ \ 765{\cdot}6 + 1190{\cdot}0 > o \\ -93{\cdot}6 + \ \ 998{\cdot}0 - 1035{\cdot}0 = -1128{\cdot}6 + \ \ 998{\cdot}0 < o \end{array}\right.$$

and

$$R\,l = 30{\cdot}617$$

$$R'\,l = 8{,}383$$

Check:

$$R\,l + R'\,l = 39{,}000 = 260 \times 150 = W\,l$$

$$R_{15} = 452$$

$$R_{30} = 1{,}596$$

$$R_{75} = 11{,}117$$

$$H\,f = R\,\frac{l}{2} - R_{75} = 4{,}192$$

Check:

$$R'_{15} = 8{,}383$$

$$R'_{30} = 4{,}935$$

$$R'_{75} = o$$

$$H\,f = R'\,\frac{l}{2} - R'_{75} = 4{,}192$$

$$H\,y_{15} = \left(H\,f.\,\frac{y}{f}\right)_{15} = 4{,}192 \times 0{\cdot}36 = 1{,}509$$

$$H\,y_{30} = H\,f \times 0{\cdot}64 = 2{,}682$$

$$\left(\frac{M}{h}\right)_{15} = [R\,l\,\frac{x}{l} - R_{15} - H\,y_{15}]\,\frac{1}{h} = [R'\,l\,\frac{x}{l-x} - R'_{15} -$$

$$- H\,y'_{15}]\,\frac{1}{h} = 50{,}000$$

$$\left(\frac{M}{h}\right)_{30} = [R\,l\,\frac{x}{l} - R_{30} - H\,y_{30})\,\frac{1}{h} = [R'\,l\,\frac{x}{l-x} - R'_{30} -$$

$$- H\,y'_{30}]\,\frac{1}{h} = 133{,}700$$

$$D_{\mathrm{II}} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = +\ 83{,}700 \text{ pounds.}$$

D_{III} *max.*—

Maximum line $= 65{\cdot}82$

Maximum span $= 65{\cdot}82$

$$\frac{d\,D}{d\,g} = -\ 0{\cdot}12\ (W_1 + w) + 5{\cdot}88\ W_2 - 117\ \frac{w'}{\Delta x}$$

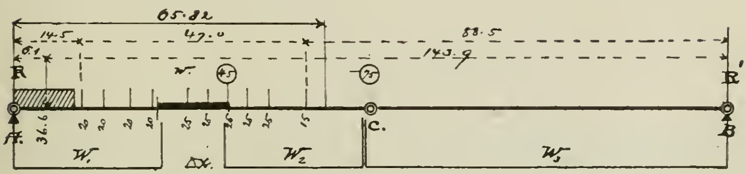


FIG. 19.

$$D_{\mathrm{III}} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = 233{,}000 - 125{,}900 =$$

$$= 107{,}100 \text{ pounds.}$$

D_{IV} *max.*—

Maximum line $= 72{\cdot}66$

Maximum span $= (g_m - a) =$ from (60) to $72{\cdot}66$

a and c being negative.

$$\frac{d\,D}{d\,g} = +\,0{\cdot}24\,w + 3{\cdot}84\,W_2 - 63\,\frac{w}{\varDelta x}$$

Third driver of first engine on (60), last wheel of tender of first engine $59{\cdot}5$ from Abutment B.

$$\frac{d\,D}{d\,g} = \begin{cases} 0{\cdot}24 \times 65 + 3{\cdot}84 \times 75 - 0{\cdot}12 \times 80 - \frac{50}{15} \times 63 = \\ \qquad = 3{,}036 - 219{\cdot}6 > 0 \\ 0{\cdot}24 \times 90 + 3{\cdot}84 \times 50 - 0{\cdot}12 \times 80 - \frac{75}{15} \times 63 = \\ \qquad = 213{\cdot}6 - 324{\cdot}6 < 0 \end{cases}$$

$$D_{IV} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = +\,55{,}200 - (-\,30{,}000) = +\,85{,}200$$

D_V *max.*—

$$D_V = \left(\frac{M}{h}\right)_{75} - \left(\frac{M}{h}\right)_{60} = -\left(\frac{M}{h}\right)_{60} = -\,260{,}600 \text{ pounds.}$$

Minima.—

$$D_I = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{0} = \left(\frac{M}{h}\right)_{15} \textit{min.} = -\,56{,}400 \text{ pounds.}$$

D_{II} *Min.*—

Min. span $= 90{\cdot}36$

$$\frac{d\,D}{d\,g} = 7{\cdot}68\,W_2 - 1{\cdot}56\,W_3$$

top hinge = dividing line

$$\frac{d\,D}{d\,g} = 64\,W - 77\,W_3$$

Third driver of first engine on top hinge, second wheel of second tender $1{\cdot}5$ from Abutment B.

$$D_{II}\,\textit{min.} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = -\,132{,}000 + 56{,}400 =$$
$$= -\,75{,}600$$

D_{III} *Min.*—

$$\text{Min. span} = 84{\cdot}18$$

$$\frac{d\,D}{d\,g} = 49\,W - 55\,W_3$$

Second driver of first engine on top hinge, first wheel of second tender 1·75 from Abutment B.

$$D_{III}\,min. = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = -\ 223{,}600 + 130{,}600 =$$

$$= -\ 93{,}000 \text{ pounds.}$$

D_{IV} *Min.*—

$$\text{Max. line } g_m = 72{\cdot}6$$

$$\text{Min. span} = a + \left(\frac{1}{2} - g_m\right) + c$$

or from o to (45) and from (72·6) to (150)

$$\frac{d\,D}{d\,g} = -\,a\,(W_1 + w) + \beta\,W_3 + c\,W_2 +$$

$$+ \frac{w}{\Delta\,x}\,[a\,x - (k - \beta\,x)]$$

$$\frac{d\,D}{d\,g} = 0{\cdot}24\,(W_1 + w)\,3{\cdot}84 + W_2 - 0{\cdot}12\,W_3 - 4{\cdot}2\,w$$

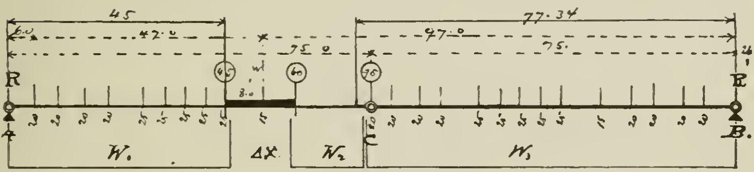


FIG. 20.

Top hinge = dividing line. To be a maximum $W_1\,g_1$ must have a load in (45).

[*Note.*—Another position of the loads answering

$$\frac{d\,D}{d\,g}$$

can be found in reversing the trains. The values of the stresses corresponding to these positions must be calculated and the absolute maximum found. I have in all instances only given the latter.]

$$D_{IV} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = -\ 54{,}900 - (+\ 12{,}400) =$$

$$= -\ 67{,}300.$$

D_V *min.*—

$$D_V = \left(\frac{M}{h}\right)_{75} - \left(\frac{M}{h}\right)_{10} = - \left(\frac{M}{h}\right)_{10} = + 258{,}600$$

Vertical Stresses P in the Posts.

For determining P maximum and P minimum always that end of the post must be selected taking up no moving loads.

(I) *One diagonal acting at the end of the post.*

(*a*) *Diagonals running from left to right corresponding to* $+ D$

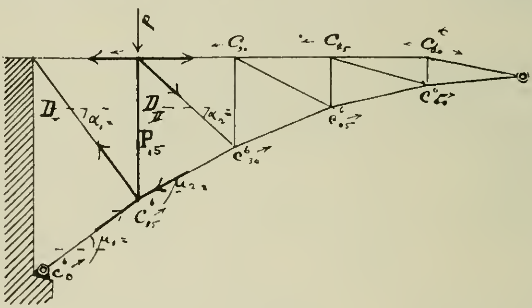


FIG. 21.

$$P_{15} = C_0 \, tan \, \mu_1 - C_{15} \, tan \, \mu_2 + D_I \, tan \, \alpha_1$$

or as :

$$D_I = C_{15} - C_0 = \Delta \, C_{15}$$

$$= C_{15} \, (tan \, \alpha_1 + tan \, \mu_2 =) - C_0 \, (tan \, \alpha_1 + tan \, \mu_1)$$

and as

$$C_0 = - H$$

$$P_{15} = 2{\cdot}04 \, C_{15} + 2{\cdot}20 \, H$$

$$2{\cdot}04 \, C_{15} = [0{\cdot}714 \, W_1 \, g_1 + W_2 \, (30{\cdot}6 - 1{\cdot}326 \, g_2) - - 0{\cdot}918 \, W_3 \, g_3] \frac{1}{22{\cdot}2}$$

$$2{\cdot}20 \, H = [0{\cdot}814 \, W_1 \, g_1 + W_2 \, (o + 0{\cdot}814 \, g_2) + + 0{\cdot}814 \, W_3 \, g_3] \frac{1}{22{\cdot}2}$$

$$P_{15} = [1{\cdot}528 \, W_1 \, g_1 + W_2 \, (30{\cdot}6 - 0{\cdot}512 \, g_2) - 0{\cdot}104 \, W_3 \, g_3] \frac{1}{22{\cdot}2}$$

$$P_{30} = C_{15}\, tan\, \mu_2 - C_{30}\, tan\, \mu_3 + D_{11}\, tan\, \alpha_2$$

or as:

$$D_{11} = C_{30} - C_{15} = \Delta\, C_{30}$$

$$= C_{30}\,(tan\, \alpha_2 + tan\, \mu_3) - C_{15}\,(tan\, \alpha_2 + tan\, \mu_2)$$

$$= 1{\cdot}32\, C_{30} - 1{\cdot}48\, C_{15}$$

$$= [0{\cdot}1776\, W_1\, g_1 + W_2\,(572{\cdot}76 - 8{\cdot}7024\, g_2) -$$

$$- 1.0656\, W_3\, g_3]\, \frac{1}{22{\cdot}2 \times 13{\cdot}8}$$

$$P_{45} = 0{\cdot}76\, C_{45} - 0{\cdot}92\, C_{30}.$$

$$= [-0{\cdot}2208\, W_1\, g_1 + W_2\,(256{\cdot}68 - 3{\cdot}5328\, g_2) -$$

$$- 0{\cdot}1104\, W_3\, g_3]\, \frac{1}{13{\cdot}8 \times 7{\cdot}8}$$

$$P_{60} = 0{\cdot}36\, C_{60} - 0{\cdot}52\, C_{45}$$

$$= [-0{\cdot}1872\, W_1\, g_1 + W_2\,(70{\cdot}20 - 0{\cdot}8112\, g_2) +$$

$$+ 0{\cdot}1248\, W_3\, g_3]\, \frac{1}{7{\cdot}8 \times 4{\cdot}2}$$

From these general equations we deduct the maximum stresses of P corresponding to positive values of D.

Maxima.—

$$P_{15} \text{ max. } (+\, D)$$

$$\text{Max. line } g_m = \frac{30{,}600}{512} = 59{\cdot}8$$

$$\text{Max. span} = a + (g_m - a) = 59{\cdot}8$$

As shown by

$$\frac{1}{22{\cdot}2}$$

P_{15} is a function of

$$\left(\frac{M}{h}\right)_{15}$$

only.

$$\frac{d\,P}{d\,g} = 1{,}528\, W_1 - 512\, W_2$$

$$= 255\, W_1 - 64\, W$$

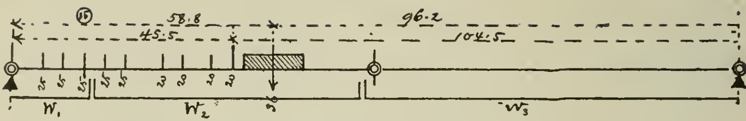


FIG. 22.

Dividing line point (15):

$$\frac{d\,P}{d\,g} = \begin{cases} 15{,}424 - 19{,}125 < o \\ 15{,}424 - 12{,}750 > o \end{cases}$$

and

$$R\ l = 29{,}278$$

$$R'\,l = 6{,}871$$

$$\text{Check } R\,l + R'\,l = 36{,}149 = 241 \times 150$$

$$R_{15} = 319$$

$$R_{30} = 1{,}875$$

$$R_{75} = 11{,}203\ H\,f = R\,\frac{l}{2} - R_{75} = 3{,}436$$

$$\text{Check } R'_{15} = 3{,}576$$

$$R'_{30} = 1{,}517$$

$$R'_{75} = o\ H\,f = R'\,\frac{l}{2} - R_{75} = 3{,}436$$

$$H\,f \div f = H = 114{,}500$$

$$\left(\frac{M}{h}\right)_{30} = 129{,}100$$

$$\left(\frac{M}{h}\right)_{15} = 61{,}800$$

$$D_{\mathrm{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{o} = \left(\frac{M}{h}\right)_{15} = 61{,}800$$

$$C_o = H = 114{,}500$$

$$C_{15} = H - \left(\frac{M}{h}\right)_{15} = 52{,}700$$

$$P_{15} = C_o\ tan\ \mu_1 - C_{15}\ tan\ \mu_2 + D_{\mathrm{I}}\ tan\ \alpha_1$$

$$= 0{\cdot}72 \times 114{,}500 - 0{\cdot}56 \times 52{,}700 + 61{,}800 \times 1{\cdot}48 =$$

$$= 114{,}500$$

Check from top chord.

$$P_{15} = D_{II} \tan \alpha_2 + p = (12{,}910 - 61{,}800) \times 0{\cdot}92 + p =$$

$$= 57{,}300 \times 0{\cdot}92 + 82{,}600 = 114{,}500$$

P_{30} *max.* $(+ D)$:

As seen from

$$\frac{1}{22{\cdot}2 \times 13{\cdot}8},$$

P_{30} is a function of

$$\left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} \text{ and goes as } D.$$

$$\text{Maximum span} = 65{\cdot}8$$

$$\frac{dP}{dg} = - a\,(W_1 + w) + \beta\ W_2 + \frac{w}{\Delta x}\,[a\,x - (k - \beta x)]$$

$$= 0{\cdot}1776\,(W_1 + w) + 8{\cdot}7024\,W_2 - \frac{w}{15} \times 306{\cdot}33$$

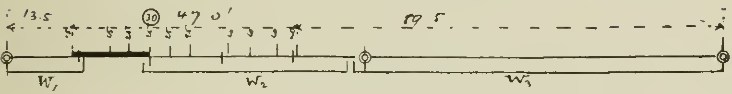


FIG. 23.

$$\frac{dP}{dg} = \left| \begin{array}{l} - 16{\cdot}0 + 1131{\cdot}3 - 1531{\cdot}6 = 1{,}131 - 1{,}547 < o \\ - 11{\cdot}5 + 1348{\cdot}9 - 1021{\cdot}1 = 1{,}349 - 1{,}043 > o \end{array} \right.$$

$$H = 139{,}700$$

$$\left(\frac{M}{h}\right)_{15} = 49{,}700$$

$$\left(\frac{M}{h}\right)_{30} = 133{,}700$$

$$\left(\frac{M}{h}\right)_{45} = 216{,}400$$

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = 84{,}000$$

$$D_{III} = 82{,}700$$

$$C_{45} \tan \mu_3 = 50{,}400$$

$$C_{30} \tan \mu_2 = 24{,}000$$

$$P_{30} = C_{45}\ tan\ \mu_3 - C_{30}\ tan\ \mu_2 + D_{III}\ tan\ \alpha_3 = 125{,}300$$

Check from top chord.

$$P_{30} = D_{III}\ tan\ \alpha_3 + p = 82{,}700 \times 0{\cdot}52 + 82{,}500 = 125{,}500$$

P_{45} *max.*—

$$\text{Maximum span} = (g_m - a) = 27{\cdot}7$$

or from (45) to (72·7).

$$\frac{dP}{dg} = -a\,(W_1 + w) + \beta\ W_2 + c\ W_3 + \frac{w}{\Delta x}\,[a\,x - (k - \beta x)]$$

$$= +\,0{\cdot}22\,(W_1 + w) + 3{\cdot}53\ W_2 - 0{\cdot}11\ W_3 - 107{\cdot}6\ \frac{w}{15}$$

Third driver of first engine in (45), last wheel of first tender 74·5 from Abutment B.

To the right of the dividing line

$$(W_1 + w) = 90$$
$$W_2 = 110$$
$$W_3 = 20$$

To the left of the divining line

$$(W_1 + w) = 65$$
$$W_2 = 135$$
$$W_3 = 20$$

$$\frac{dP}{dg} = \begin{array}{l} 14{\cdot}3 + 476{\cdot}5 - 2{\cdot}2 - 359{\cdot}0 = 490{\cdot}8 - 361{\cdot}2 > o \\ 19{\cdot}8 + 383{\cdot}3 - 2{\cdot}2 - 538{\cdot}0 = 403{\cdot}1 - 540{\cdot}2 < o \end{array}$$

$$P_{45} = C_{45}\ tan\ \mu_3 - C_{30}\ tan\ \mu_2 + D_{III}\ tan\ \alpha_3 = D_{IV}\ tan\ \alpha_4 + p =$$

$$= 93{,}500.$$

P_{60} *max.*—

$$\text{Maximum line } g_m = 86{\cdot}6$$

Maximum line from (60) to end of truss (150).

$$\frac{dP}{dg} = -a\,(w) + \beta\ W_1 + c\ W_3 + \frac{w}{\Delta x}\,[a\,x - (k - \beta\,x)]$$

$$= +\,0{\cdot}187\,(w) + 0{\cdot}811\ W_2 + 0{\cdot}125\ W_3 - 32{\cdot}7\ \frac{w}{\Delta x}$$

First wheel 47·75 from Abutment A, second wheel of second tender, 1·25 from Abutment B.

$$P_{60} = C_{45}\ tan\ \mu_3 - C_{60}\ tan\ \mu_4 + D_{IV}\ tan\ \alpha_4 = D_V\ tan\ \alpha_5 + p =$$
$$= 98{,}100 \text{ pounds.}$$

(*b*) *Diagonals running from the right to the left corresponding to minus D.*

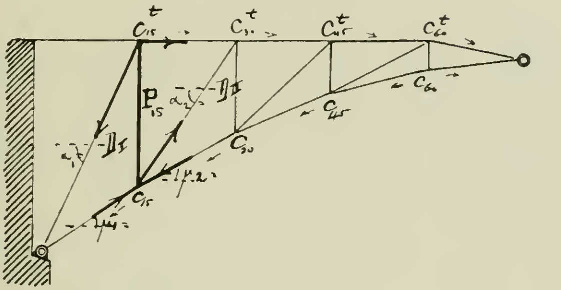


FIG. 24.

$$P_{15} = C_{30}\,(tan\ \alpha''_2 - tan\ \mu_2) - C_{15}\,(tan\ \alpha''_2 - tan\ \mu_1)$$
$$= 0·92\ C_{30} - 0·76\ C_{15}$$
$$= [1·435\ W_1\, g_1 + W_2\,(455·40 - 8·5008\ g_2) -$$
$$- 2·4288\ W_3\, g_3\,]\ \frac{1}{22·2 \times 13·8}$$

$$P_{30} = C_{45}\,(tan\ \alpha''_3 - tan\ \mu_3) - C_{30}\,(tan\ \alpha''_3 - tan\ \mu_2$$
$$= 0·52\ C_{45} - 0·36\ C_{30}$$
$$= [0·3774\ W_1\, g_1 + W_2\,(238·68 - 3·9936\ g_2) -$$
$$- 0·8112\ W_3\, g_3\,]\ \frac{1}{13·8 \times 7·8}$$

$$P_{45} = C_{60}\,(tan\ \alpha''_4 - tan\ \mu_4) - C_{45}\,(tan\ \alpha''_4 - tan\ \mu_3)$$
$$= 0·24\ C_{60} - 0·12\ C_{45}$$
$$= [0·3360\ W_1\, g_1 + W_2\,(108·36 - 1·6464\ g_2) -$$
$$- 0·2016\ W_3\, g_3]\ \frac{1}{7·8 \times 4·2}$$

From these general equations we deduct the maximum stresses corresponding to negative values of D.

P_{15} *max.* (— *D*). —

$$\text{Max. line} = \frac{544 \cdot 40}{8 \cdot 5008} = 53 \cdot 5$$

Max. span = minimum span of — *D*

$$= \left(\frac{l}{2} - g_m\right) + c = 96 \cdot 5$$

$$\left(\frac{d\,P}{d\,g}\right) = 85{,}008\ W_2 - 24{,}288\ W_3$$

$$= W - 1 \cdot 286\ W_3$$

Dividing line = top hinge, the point (15) not being in the maximum span.)

(See *Fig. 17.*)

$$P_{15} = C_{15}\ tan\ \mu_1 - C_{30}\ tan\ \mu_2 + D_{II}\ tan\ a_{II} = D_I\ tan\ a_1 =$$
$$= 124{,}100$$

The above position of the loads for P_{15} maximum corresponds to the position of loads making D_I a minimum.

From the general equation follows, that stress P_{15} is a function of D_{II}, but in the case of $p = o$, or when no moving load is taken up in the panel point, P_{15} becomes a function of D_I, the above position of the loads corresponding to D_I min., showing how difficult it would be to determine the correct position of the loads, inducing the maximum or minimum stress, if p had to be taken into consideration and how necessary it is to eliminate p in defining the maximum or minimum of the stress.

P_{30} *max.* (— *D*)—

$$\text{Max. line } g_m = 59 \cdot 7$$

$$\text{Max. span} = \left(\frac{l}{2} - g\right) + c = 90 \cdot 3$$

$$\left(\frac{d\,P}{d\,g}\right) = W - 1 \cdot 2\ W_3$$

Position of loads as for D_{II} min. (see D_{II} min.).

$$P_{30} = D_{II}\ tan\ a''_2 = 1 \cdot 48 + 75{,}500 = 111{,}800$$

P_{45} *max.* (— D).—

$$\text{Max. line } g_m = 65{\cdot}68$$

$$\text{Max. span} = \left(\frac{l}{2} - g_m\right) + c = 84{\cdot}32$$

$$\frac{dP}{dg} = 16{,}464\ W_2 - 2{,}016\ W_3$$

$$= W - 1{\cdot}723\ W_3$$

First wheel 62·75 from Abutment A, first wheel of second tender 0·75 from same abutment, corresponding to D_{III} minimum.

$$P_{45} = D_{III}\ tan\ \alpha''_3 = 0{\cdot}92 \times 93{,}000 = 85{,}600 \text{ pounds.}$$

[*Note.*—It is necessary, when diagonals in tension only are acting, to compute, in *every instance*, the general equations of P corresponding to minus D, as by no means can be foretold whether plus D or minus D will produce the greatest stresses in the posts.]

(II) *Two Diagonals Acting Together at the End of the Post.*

The stresses from two diagonals in tension acting together at the end of the post, are, as we know, smaller than those from one diagonal, and no further investigations are necessary.

(III) *No Diagonal Acting at the End of the Post.*

As known, the stress is smaller than the vertical component of the maximum or minimum chord stress.

Maximum:

$$P_{15} = C_{15}\ min. \times 0{\cdot}16 = -\ 64{,}200$$

$$P_{10} = C_{60}\ min. \times 0{\cdot}16 = -\ 71{,}000$$

$$P_{45} = C_{45}\ min. \times 0{\cdot}16 = -\ 80{,}600$$

$$P_{60} = C_{60}\ min. \times 0{\cdot}16 = -\ 82{,}500$$

$$tan\ \mu_{x+\Delta x} - tan\ \mu_x = 0{\cdot}16$$

for all the points.

These stresses being smaller than those from one diagonal, no further investigation is necessary.

Minimum.—With two *diagonals in tension* at the end of the posts, it is evident that no tensile stress can occur in the post.

Hence P_{15}, P_{30}, P_{45} are exempt of tensile stresses, not so P_{60}.

P_{60}.—Remembering that the bottom chord is deciding the maximum and minimum stress of P, we see that P_{60} can have only one diagonal or no diagonal acting at its end.

The latter position is in so far different from the other posts, as D_{V} can be also in compression.

Beginning with *Tension* we have, to start with, the position of C_{60} maximum, which chances to correspond without further shifting to P_{60} maximum, as D_{IV} is negative,

$$D_{\mathrm{V}} = o$$

and

$$C_{60}\,(tan\ \mu_5 - tan\ \mu_4)$$

the greatest value possible.

Hence

$$P_{60}\ min. = 96{,}600 \times 0{\cdot}16 = 15{,}500 \text{ tension.}$$

Check from top chord.

$$P_{60} = D_{\mathrm{V}}\ tan\ a_5 + D_{\mathrm{IV}}\ tan\ a_4 + p = 232{,}400 \times 0{\cdot}2 + 700 \times$$
$$\times\ 0{\cdot}52 + 31{\cdot}200 = 15{,}600$$

Compression:

Starting with C_{60} min., we find D_{IV} positive. Moving to the left we find the position corresponding to $D_{\mathrm{IV}} = o$ thus:

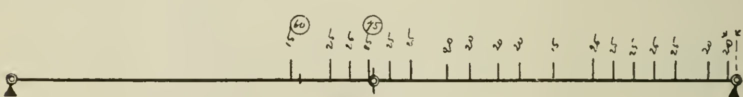


Fig. 25.

and

$$P_{60} = 503\ {\cdot}800 \times 0{\cdot}16 = 80{,}600$$

Check from top chord.

$$P_{60} = D_{\mathrm{V}}\ tan\ a_5 + p = 217.700 \times 0{\cdot}2 + 36{,}800 = 80{,}400$$

In the same way can also be found the correct values of P maximum and P minimum, when two diagonals in tension are acting.

With these data the actual stresses in the members are calculated as follows:

Chord Members:

The *direction* of the stress in the chord members, *which cannot be foretold*, is deducted from the position of the diagonals in the panels. For this reason the horizontal component of the stresses in the diagonal or D, corresponding to the position of the loads producing the maximum or minimum stress in the chord members, have been calculated (see chord stresses). Computing these values of D we find the direction of the stresses in the chords, as shown in *Fig. 26* and *Fig. 27*.

Calling μ the angle of the member with the horizontal, the stress in the inclined chord becomes

$$C_x \div cos\ \mu_x$$

Top Chord.—

Maxima (positive moments, top chord in compression):

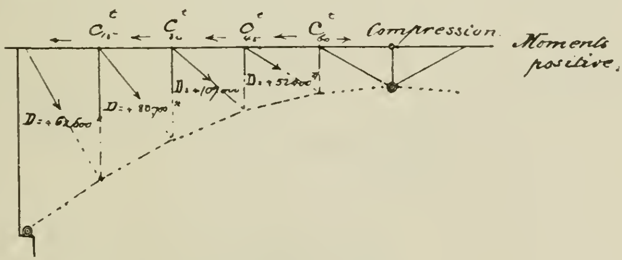


FIG. 26.

First panel = 62,600

Second panel = 137,300

Third panel = 233,100

Fourth panel = 260,600

Minima (negative moments, top chord in tension):

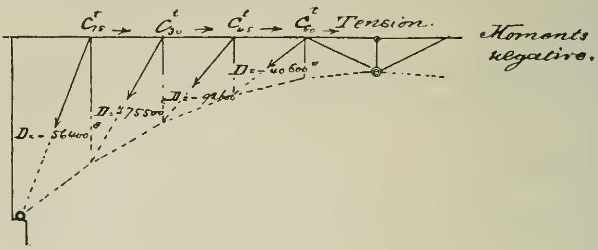


FIG. 27.

First panel = 0

Second panel = 56,400

Third panel = 131,900

Fourth panel = 223,500

Bottom Chord.—

Maxima (positive moments, bottom chord in tension):

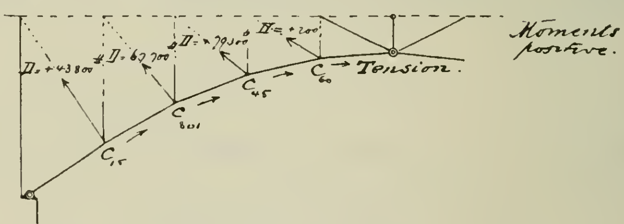


FIG. 28.

First Panel Note.—

$$\left(\frac{M}{h}\right)_0 - H = - H$$

as

$$\left(\frac{M}{h}\right)_0 = o$$

Hence max. = min. $H = o$

Second panel = + 16,700

Third panel = + 58,400

Fourth panel = + 111,400

Fifth panel = + 96,900

Minima (negative moments, bottom chord in compression):

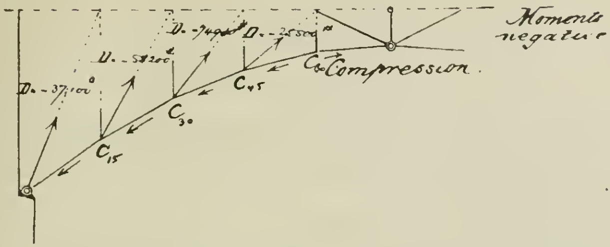


FIG. 29.

First panel = 495,200

Second panel = 509,000

Third panel = 542,700

Fourth panel = 530,000

Fifth panel = 517,000

Diagonals.—The stress in the inclined member will be

$$D \div \cos a$$

Maxima:

First panel = + 112,000

Second panel = + 113,700

Third panel = + 121,000

Fourth panel = + 88,500

Fifth panel = — 265,600 (compression)

Minima:

First panel = + 136,300

Second panel = + 135,200

Third panel = + 126,300

Fourth panel = + 75,900

Fifth panel = 263,600 (tension).

Posts:

$$P_{15} = -\ 114,500$$

$$P_{30} = - \ 125{,}300$$

$$P_{45} = - \ 93{,}500$$

$$P_{60} = + \ 15{,}500 \text{ (tension).}$$

$$P_{60} = - \ 98{,}300 \text{ (compression).}$$

Fastening of Shoe.—The bolts fastening the shoe have to take up R maximum in proportion to the inclination of the seat of the abutment.

Adding these stresses and the stresses from dead load, we find the following strain sheet for *one truss*, in dividing the figures by 2.

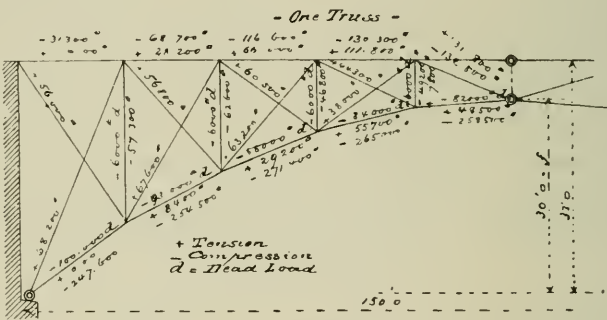


FIG. 30.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, November 15, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Dr. Jayne presented a report on behalf of the special committee appointed to arrange for a reception to be given to Professor Wiley, on the evening of December 6, 1892.

On motion, the report was accepted and the committee was given power to arrange the necessary details.

Nominations for officers for the ensuing year were then made as follows :

For *President*, ...	Prof. Edgar F. Smith, Dr. Wm. H. Greene.
For *Vice-Presidents* (two to be elected), . .	Mr. Henry Bower, Dr. D. K. Tuttle.
For *Secretary*, ...	Dr. Wm. C. Day.
For *Treasurer*, ...	Dr. H. W. Jayne.
For *Conservator*, ...	Dr. Wm. H. Wahl.

Mr. H. Pemberton, Jr., on behalf of himself and Mr. George P. Tucker, read a paper on "Deposits of Native Soda near Laramie, Wyoming." Referred for publication.

Dr. Wm. H. Wahl read a paper, entitled "Observations on Ferro-Tungsten." Both papers called forth considerable discussion.

The Section then adjourned.

H. PEMBERTON, JR., *Secretary pro tem.*

REPORT OF THE PROCEEDINGS OF THE NINTH ANNUAL MEETING OF OFFICIAL AGRICULTURAL CHEMISTS, HELD AT WASHINGTON, AUGUST 25–27, 1892, WITH SPECIAL REFERENCE TO THE METHODS ADOPTED FOR THE CONTROL OF THE FERTILIZER TRADE.

By Dr. Bruno Terne.

[*Read at the stated meeting of the Chemical Section, held October 18, 1892.*]

Mr. President and Members of the Chemical Section:

Looking over the wide field of scientific societies, and more especially over the chemical organizations of our country, I know of none which has, in the short time since its creation, done so much practical good work for the benefit of the interested circles as the Association of Official Agricultural Chemists.

Still, when we come to criticise its work of the last few years, we cannot deny the fact that the results gained are not in proportion to the work done Although encouraging, the results are far from being final.

A short historical sketch of the association will doubtless interest you, and serve as an introduction to the remarks which I propose to make in regard to the results of the last meeting of the said association.

With the revival of business in the Southern States the consumption of fertilizing materials for the cotton plantations soon assumed enormous proportions.

The valuation of this material, based on chemical analysis, was a source of great trouble both to seller and buyer, caused by the unconcerted action of the chemical laboratories.

There were in use all possible methods for the determination of the different ingredients.

This chaotic state of affairs has been changed by the concerted action of the analytical chemists interested in such work, and the gain of this very important point is the fruit of the earnest work of this association.

The beginning of the organization dates from the following circular-letters:

DEPARTMENT OF AGRICULTURE,
ATLANTA, Ga., May 20, 1880.

DEAR SIR:—The experience of the last fertilizer season has suggested to my mind the importance of securing such uniformity of method in determining, by chemical analysis, the percentage of valuable ingredients in commercial fertilizers, as will give more uniform, and hence more satisfactory results. This is especially desirable in determining reverted phosphoric acid.

With a view to accomplishing so desirable an object, as well as others which may be deemed proper, I have the honor to suggest the calling of a convention of the several Commissioners of Agriculture, representatives from State Boards of Agriculture, State chemists and professors of chemistry in State universities and State agricultural colleges, in those States using large amounts of commercial fertilizers, to meet at some convenient point early in the month of July next.

I would be glad to have your views on the subject; and if favorable to the suggestion please nominate some gentleman who, by general assent, may be informally authorized to fix the time and place of such convention, and issue the necessary notices. You are also requested to give me the names and post-offices of gentlemen in your State, holding either of the above positions indicated, which do not appear in the list below, that copies of this circular may be sent to them. An early reply is desirable.

Very respectfully,
J. T. HENDERSON,
Commissioner of Agriculture.

DEPARTMENT OF AGRICULTURE,
ATLANTA, Ga., July 1, 1880.

DEAR SIR:—I am gratified to announce that the recent circular-letter which I had the honor to issue, suggesting the calling of a convention for the purpose of adopting a

uniform system for the analysis of commercial fertilizers, has met with favorable responses from a large majority of the gentlemen to whom it was sent. A like majority has imposed upon me the duty of fixing the time and place of said convention, and issuing the necessary notices for the same. After correspondence with others, and due consideration of the interests involved, I have decided upon Wednesday, the 28th of July, as the time, and Washington, D. C., as the place for the assembling of the proposed convention. You are, accordingly, respectfully and earnestly invited to be present and participate in the convention.

Every reasonable facility for the deliberations of the convention will be afforded by Hon. Wm. G. LeDuc, Commissioner of Agriculture, who is in hearty sympathy with the object sought to be accomplished. I have appended hereto a list of the names of gentlemen to whom this circular will be sent.

Trusting that you will find it convenient to attend and give the convention the benefit of your experience, and requesting that you will at once inform me by letter whether you will attend, I am, Respectfully,

J. T. HENDERSON,
Commissioner of Agriculture.

The first convention met on the day set for and adopted methods for the determination of phosphoric acid, nitrogen and potash to be used during the ensuing year.

This meeting was followed by meetings in Cincinnati, Atlanta, and in 1884 in Philadelphia.

The convention in our city was the most important one for the organization, because the association adopted (September 9th) the new Constitution, and made itself entirely independent of its former connections as a subdivision of the Section of Chemistry of the American Society for the Advancement of Science,

The first two paragraphs of the Constitution are of general interest.

(1) "This association shall be known as the Association of Official Agricultural Chemists in the United States. Its

object shall be to secure, as far as possible, uniformity in legislation with regard to the regulation of the sale of commercial fertilizers in the different States and uniformity and accuracy in the methods and results of fertilizer analysis.

(2) "Analytical chemists connected with Departments of Agriculture, State Agricultural Experiment Stations and State Boards, exercising an official fertilizer control, shall alone be eligible to membership; and one such representative from each of these institutions, when properly accredited, shall be entitled to a vote in the association. All analytical chemists and others interested in the objects of the association may attend its meetings and take part in its discussions, but shall have no vote in the association."

The exclusion of all chemists not to be classified as officials, from full membership, varies from the custom of England and Germany.

It is not my intention to question either the motive or the wisdom of this regulation, or of another rule denying the right to enter a motion which has been in force since 1891, as it certainly gives the excluded more liberty to criticise than if he were made responsible by his vote for the action of the society.

Since the Philadelphia meeting the society has made its headquarters in Washington, where, under the patronage of the Department of Agriculture, the annual meetings are held. The untiring efforts of the Secretary of the society, Mr. Harvey W. Wiley, Chief Chemist of the Department of Agriculture, have secured to the association the support of the Administration, and enabled the same to publish the results of their annual work, as a *Bulletin* of the Department, division of chemistry.

These annual reports are edited by the able pen of Professor Wiley and are an excellent guide for all connected with the interests of the society.

The scope of work of the association has extended to a wider field than was originally planned, including at present all station work in the interest of the farming community.

Besides the fertilizers analysis, we have had during the last year reports on analysis of fermented liquors, dairy

products, foods rich and poor in carbo-hydrates, and on sugar.

During the last four years I have regularly attended the meetings of the association as a non-member, and taken much interest in the analysis of commercial fertilizers.

It was with great pleasure that I attended the meetings from August 25th to 27th of this year.

I will now report the proceedings, referring for the methods in use to the official *Bulletin* No. 31, 1891:

REPORT ON POTASH.

For the Association of Official Agricultural Chemists of the United States.

By Dr. George F. Payne, Atlanta, Ga.

The work required by the association, of the reporter on potash for 1892, was an investigation as to whether the use of sodium chloride was essential in the Lindo-Gladding method of determining potash.

Four samples were prepared and were numbered one, two, three and four.

No. 1 was a high grade sulphate of potash.

No. 2 was an acid phosphate with sulphate of potash in the form of kainit.

No. 3 was an acid phosphate with sulphate of potash in the form of kainit, and containing five per cent. of double sulphate of alumina and ammonia.

No. 4 was identical with No. 3 with the substitution of five per cent. of soluble sodium silicate in place of the double salt of alumina and ammonia.

The ingredients of each sample were first finely powdered and thoroughly mixed, then sifted through a very fine sieve, then again intimately mixed and portions taken from forty different parts of the pile were well re-mixed and used for filling the bottles. Only the best XX superfine long taper corks were used, and were selected long enough to project well from the mouth of the vial to secure easy opening and air-tight re-corking. The corks were all well sealed with paraffine. With each package a circular was sent requesting that the determinations be made as soon as convenient after receiving samples to eliminate as far as possible any differences likely to occur from changes in the amount of moisture after bottling.

Each chemist was also requested to carry out the method as ordinarily managed in his laboratory, working each sample with and without sodium chloride, side by side, and as nearly as possible under exactly the same conditions.

Twenty-two chemists took part in the work and their results were as follows: [See table inserted here.]

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DETERMINATION OF POTASH BY THE LINDO-GLADDING METHOD WITH AND WITHOUT SODIUM CHLORIDE.

NAMES OF ANALYSTS AND LOCATION.	Sample No. 1.		Sample No. 2.		Sample No. 3.		Sample No. 4.	
	With NaCl.	Without NaCl.	With NaCl.	Without NaCl.	With NaCl.	Without NaCl.	With NaCl.	Without NaCl.
OFFICIAL LABORATORIES.								
Norman Robinson, State Chemist, Tallahassee, Fla.,	48·83	48·70	1·58	1·59	1·47	1·46	1·40	1·41
F. S. Shiver, Assistant of State Chemist, Fort Hill, S. C. (*a*),	49·05	49·13	1·45	1·44	1·40	1·39	1·40	1·44
F. S. Shiver, Assistant of State Chemist, Fort Hill, S. C. (*b*),	49·00	—	1·45	—	1·40	—	1·32	—
P. L. Hutchinson, Assistant of State Chemist, Atlanta, Ga.,	49·05	49·15	1·50	1·48	1·51	1·40	1·48	1·40
J. F. Wilkinson, Assistant of State Chemist, Atlanta, Ga.,	49·13	49·12	1·50	1·52	1·47	1·42	1·36	1·34
F. B. Carpenter, Experiment Station, Raleigh, N. C.,	48·94	—	1·61	—	1·48		1·56	—
Thos. L. Blalock, Experiment Station, Raleigh, N. C. (*a*),	48·76	48·76	1·63	1·63	1·48	1·46	1·48	1·47
Thos. L. Blalock, Experiment Station, Raleigh, N. C. (*b*),	48·96	49·10	—	—	—	—	—	—
Thos. L. Blalock, Experiment Station, N. C. (*c*),	48·90	48·91	1·59	1·58	1·51	1·48	1·46	1·45
Louis A. Voorhees, Experiment Station, New Brunswick, N. J.,	49·23	49·19	1·49	1·46	1·35	1·36	1·36	1·37
Louis A. Voorhees, Experiment Station, New Brunswick, N. J.,	49·27	49·29	1·51	1·52	1·38	1·42	1·36	1·37
Chas. S. Cathcart, Agricultural College, New Brunswick, N. J.,	49·31	49·34	1·52	1·46	1·43	1·45	1·35	1·33
E. H. Farrington, Experiment Station, Champaign, Ill.,	49·29	49·00	1·77	1·64	1·77	1·66	1·62	1·51
Thos. L. Watson, Experiment Station, Blacksburg, Va., Assistant Chemist,	49·19	48·95	1·55	1·58	1·41	1·4[illegible]	1·41	1·36
R. C. Kedzie, Agricultural College P. O., Mich.,	48·75	48·69	1·55	1·53	1·54	1·51	1·67	1·65
Rudolph de Roode, Experiment Station, Morgantown, W. Va.,	48·96	48·96	1·52	1·55	1·42	1·42	1·37	1·39
Rudolph de Roode, Experiment Station, Morgantown, W. Va.,	49·04	49·04	1·57	1·53	1·48	1·46	1·39	1·37
C. E. Collingwood, Experiment Station, Tucson, Ariz.	48·62	48·38	1·51	1·47	—	—	—	—
Henry E. Curtis, Experiment Station, Lexington, Ky.,	49·00	48·91	1·45	1·46	1·43	1·40	1·39	1·37
W. S. Sweetser, Experiment Station, State College P. O., Pa.,	49·26	49·28	1·69	1·57	1·58	1·53	1·4[illegible]	1·4[illegible]
W. S. Sweetser, Experiment Station, State College P. O., Pa.,	49·30	49·29	1·62	1·57	1·51	1·51	1·45	1·40
H. B. McDonnell, State Chemist, College Park P. O., Md.,	48·47	48·69	1·65	1·61	1·58	1·55	1·48	1·45
W. D. Bigelow, U. S. Department of Agriculture, Washington, D. C.,	48·56	48·31	1·49	1·58	1·57	1·37	1·47	1·42
Average,	48·994	48·961	1·554	1·538	1·484	1·456	1·439	1·417
Difference,	—	·033	—	·016	—	·028	—	·022
UNOFFICIAL LABORATORIES.								
Shepard Laboratory, Charleston, S. C.,	49·88	49·80	1·87	1·91	1·75	1·74	1·60	1·55
Elwyn Waller School of Mines, Columbia College, New York City,	49·67	49·17	1·60	1·46	1·61	1·53	1·59	1·59
Elwyn Waller School of Mines, Columbia College, New York City,	49·89	48·71	1·62	1·52	1·56	1·54	—	1·53
Elwyn Waller School of Mines, Columbia College, New York City,	—	48·21	—	—	—	—	—	—
Elwyn Waller School of Mines, Columbia College, New York City,	—	48·69	—	—	—	—	—	—
H. T. Vulte, Assistant of Elwyn Waller School of Mines, Columbia College, New York City,	48·88	48·54	1·66	1·58	1·58	1·58	1·58	1·52
B. C. Hinman, Assistant of Elwyn Waller School of Mines, Columbia College, New York City,	—	48·99	—	1·51	1·67	1·40	1·41	1·40
F. S. Hyde, Student of School of Mines, Columbia College, New York City,	49·43	49·47	1·35	1·42	—	—	—	—
Average,	49·550	48·948	1·620	1·566	1·634	1·544	1·560	1·518
Difference,	—	·602	—	·054	—	·090	—	·042
Total average,	49·093	48·957	1·566	1·545	1·543	1·474	1·458	1·430
Difference,	—	·136	—	·021	—	·039	—	·0[illegible]

	Sample No. 1.	Sample No. 2.	Sample No. 3.	Sample No. 4.
Highest,	49·89	1·87	1·77	1·67
Lowest,	48·62	1·35	1·35	1·32
Difference,	1·27	0·52	0·42	0·35

The method of Lindo-Gladding for potash determination is a very satisfactory one. The addition of NaCl is absolutely unnecessary, and will now be stricken out of the official methods.

The great differences in potash which often arise between guarantee of brand and anaylsis are not to be attributed to the method, but in most of the cases to the unequal mixing of the products.

I have shown in a paper read before the association at the August meeting of 1891, *Bulletin* No. 31, pp. 150, 152, the extreme difficulty of making mechanical mixtures sufficiently uniform to cover chemical guarantees, when for example eighty pounds or even 100 pounds of high grade muriate of potash at a guarantee of fifty per cent. potash, the bearer of the potash in a ton of mixture.

The same experience has been made by others, and the reports on potash give a vivid picture of this evil, which seems to grow as we go further South.

The report on determination of nitrogen was made by Mr. Van Slyke, of Seneca, N. Y. The report appears in the accompanying table. [See p. 7.]

The work on determination of nitrogen has, from the beginning, given the most satisfactory results.

The introduction of the Kjeldahl methods several years ago has given occasion for the careful testing of this method in its original and modified form.

In 1887, Prof. M. A. Scovell, of Louisville, Ky., introduced a modification to make the Kjeldahl method likewise applicable to nitrates by the use of salicylic acid (*Bulletin* No. 16, 1887, pp. 51–54) which at the meeting of 1888 was adopted as official.

The methods adopted as official methods:

(1) The absolute or cupric oxide method.
(2) The Kjeldahl method, not applicable in presence of nitrate.
(3) The Kjeldahl method, modified by Scovell, applicable to all fertilizers containing nitrates.

REPORT ON THE DETERMINATION OF NITROGEN (VAN SLYKE.)

I. Bone Meal.				II. Cotton-seed Meal.				State.	Analyst.	III. Sodium Nitrate.	
Kjeldahl Method with Permanganate.	Kjeldahl Method without Permanganate.	Gunning Method with Permanganate.	Gunning Method without Permanganate.	Kjeldahl Method with Permanganate.	Kjeldahl Method without Permanganate.	Gunning Method with Permanganate.	Gunning Method without Permanganate.			Ulsch Method.	Kjeldahl-Scoville Method.
first.	*second.*	*third.*	*fourth.*	*first.*	*second.*	*third*	*fourth.*				
4·41	4·42	4·40	4·39	7·15	7 12	7·14	7·15	Arkansas.	Teller.		
4·46	4·48	4·50	4·42	7·17	7·23	7·31	7·09	Illinois.	Farrington.		
4·50	4·43	4·45	4·46	7·27	7·16	7·18	7·22	Kentucky.	Curtis.		
4·44	4·46	4 4[illegible]	4·44	—	—	—	—	Michigan.	Miller.		
4·52	—	—	4·49	7·31	—	—	7·29	New Jersey.	Voorhees.	16·41	
4·47	—	—	4·45	7 30	—	—	7·23	New Jersey (Rutgers)	Cathcart.	16·33	
4·49	4·46	4·47	4·45	7·33	7 23	7·22	7·27	New York (Geneva)	Van Slyke.	—	
4·46	4·42	4·40	4·42	7·27	7·20	7·20	7.19	New York (Geneva)	Knisely.	16·17	
4·49	4·53	4·56	4·51	7·45	7 36	7·48	7·45	North Carolina.	Carpenter.	14·47	16·44
4.41	4·29	—	4·35	7·15	7·10	—	7·10	Pennsylvania.	Fields.	15·88	
4·52	4·38	—	4·56	7·34	7·04	—	—	U. S. Bio-Ch Lab.	Emery.	—	
—	—	—	—	—	—	—	—	Department of Agricult.	Trescott.	16·34	16·36
4·47	4·49	4·48	4·47	7·32	7·24	7·29	7·26	West Virginia.	De Roode.		
4 42	4·38	4·45	4 31	7·24	7·14	7·28	7·05	Wisconsin.	Woll.		
4·47	4·43	4·46	4·44	7·27	7·18	7 26	7·21	Averages.			
4·52	4.53	4·56	4·56	7·45	7·36	7·48	7·45	Highest.			
4·41	4·29	4·40	4·31	7·15	7·04	7·14	7·05	Lowest.			
0·11	0·24	0·16	0·25	0·30	0·32	0·34	0·40	Difference.			

(4) The Ruffle method, applicable for all fertilizers containing nitrates.

(5) The soda-lime methods, not applicable for nitrates are all equally reliable in the hands of a careful analyst.

The Kjeldahl method is without any doubt an excellent method and especially adapted for station work, where the work can be suitably arranged to divide labor with a large quantity of samples of like character.

I find that most the station chemists work with this method, while on the other hand the trade chemists and most the chemists of manufacturers are using the soda-lime or Ruffle method, because, if one has to handle only a single sample at a time, one saves time in doing so.

Differences in low grade goods (two to three per cent. ammonia) should not be higher than 0·1 per cent., and in high grade never reach 0·5 per cent.

My experience during the last fifteen years has been that I never had material difference on this point with reliable trade or station chemists, but not so with chemists who instead of normal acid use diluted muriatic acid to absorb the ammonia and simply evaporate and weigh as muriate of ammonia. With such I never could agree.

It is hard to believe that at the present day such means should be applied by analytical chemists, but it has been the case until very recently, and is so doubtless yet in single instances.

On the whole the determination of nitrogen by the station chemists in the control of the work of fertilizers has given general satisfaction.

The most important part of a fertilizer material is without question phosphoric acid in its different forms, as water soluble, reverted or citrate of ammonia soluble, and insoluble, as well as total.

The determination of phosphoric acid is of such importance for the fertilizer trade that since the first meeting of the association strenuous efforts have been made to give concordant results.

How far the association has been successful is best shown by a recapitulation of the work done. I have gone back for five years, and now give you on accompanying tables the different reports in condensed form.

1888.

August 16, 17 and 18.

Three Samples Sent Out.

(*A*) South Carolina acid phosphate.

(*B*) English acid phosphate.

(*C*) Navassa acid phosphate laboratories have sent results.

	Moisture.	Soluble.	Reverted.	Insoluble.	Total.	Available.	Averages of Available Phosphoric Acid.
A	18·14	5·58	4·45	2·60	12·63	10·03	
	18·22	5·83	4·37	2·40	12·60	10·20	Mean, 10·45
	—	6·04	4·09	2·41	12·54	10·13	Highest, 11·51
	20·96	6·00	4·11	2·38	12·49	10·11	Lowest, 10·03
	17·25	6·10	4·65	2·35	13·10	10·75	
	18·10	6·15	5·36	2·17	13·68	11·51	Difference, 1·48
B	15·03	9·38	2·17	·43	11·98	11·55	
	17·07	9·48	2·24	·43	12·15	11·72	Mean, 11·31
	—	9·31	2·23	·20	11·74	11·54	Highest, 12·25
	16·15	9·34	2·41	·35	12·10	11·75	Lowest, 11·54
	15·65	9·35	2·90	·85	13·10	12·25	
	12·85	9·26	2·81	·50	12·57	12·07	Difference, 0·71
C	6·42	9·63	5·17	4·73	19·53	14·80	
	6·31	9·53	6·06	4·11	19·70	15·59	Mean, 15·31
	—	10·81	4·78	3·71	19·30	15·59	Highest, 15·59
	7·31	8·57	6·88	4·06	19·51	15·45	Lowest, 14·80
	5·40	8·60	6·10	4·25	19·25	15·00	
	7·45	8·78	6·68	4·32	10·78	15·96	Difference, 0·79

1889.

Five Samples Sent Out.

No. 1. Ground South Carolina phosphate.
No. 2. Ground tankage.
No. 3. Ammoniated super phosphate.
No. 4. Dissolved South Carolina phosphate.
No. 5. Dissolved Navassa phosphate.

AVERAGES.

	Number of Determinations.	Average.	Highest.	Lowest.	Difference.
Sample No. 1.					
Moisture, ...	17	·95	1·37	·76	·61
Phosphoric acid, ...	31	28·07	28·78	27·47	1·31
Sample No. 2.					
Moisture, ...	17	6·79	7·64	6·03	1·61
Phosphoric acid, ...	31	14·31	14·91	13·62	1·29
Sample No. 3.					
Moisture, ...	24	15·40	19·65	12·00	7·65
Soluble phosphoric acid, . . .	32	7·11	8·57	6·00	2·57
Rev. " " . . .	32	1·31	2·27	·80	1·47
Available " " . . .	32	8·42	9·60	7·92	1·08
Insoluble " " . . .	32	1·65	2·20	1·30	·90
Total " " . . .	32	10·07	11·49	9·63	1·86
Sample No. 4.					
Moisture, ...	24	9·61	11·14	9·03	2·11
Soluble phosphoric acid, . . .	32	10·88	11·51	8·67	2·84
Rev. " " . . .	32	2·93	5·21	1·21	4·00
Available " " . . .	32	13·81	14·29	12·37	1·92
Insoluble " " . . .	32	1·95	2·81	1·28	1·53
Total " " . . .	32	15·76	16·20	15·18	1·02
Sample No. 5.					
Moisture, ...	24	9·63	15·80	8·09	7·71
Soluble phosphoric acid, . . .	32	7·52	10·04	6·00	4·04
Rev. " " . . .	32	7·50	9·08	4·48	4·57
Available " " . . .	32	15·11	15·90	14·52	1·38
Insoluble " " . . .	32	3·40	3·86	2·93	·93
Total " " . . .	32	18·51	19·19	18·06	1·15

1890.

Three Samples Sent Out.

No. 1. Guano.
No. 2. Acid phosphate.
No. 3 Ammoniated super phosphate.

AVERAGES.

	Number of Determinations.	Average.	Highest.	Lowest.	Difference.
Sample No. 1.					
Moisture,	8	13·91	16·02	12·05	3·97
Total phosphoric acid,	15	22·43	22·90	21·81	1·09
Sample No 2.					
Moisture,	10	16·35	17·82	15·20	2·62
Soluble phosphoric acid,	14	10·97	11·21	10·60	·55
Rev. " "	14	2·15	2·84	1·81	1·03
Available " "	15	13·15	13·64	12·64	1·00
Insoluble " "	15	1·81	2·16	1·53	·63
Total " "	15	14·96	15·48	14·38	1·10
Sample No. 3.					
Moisture,	8	10·99	13·65	10·18	3·47
Soluble phosphoric acid,	14	6·83	7·05	6·61	·44
Rev. " "	14	2·04	2·21	1·70	·51
Available " "	14	8·89	9·20	8 53	·67
Insoluble " "	14	1·76	2·02	1·57	·45
Total " "	14	10·67	11·04	10·15	·89

1891.

Three Samples Sent Out.

No. 1. A super phosphate.
No. 2. A complete fertilizer.
No. 3. A complete fertilizer.

(Containing cotton-seed meal and other substances difficult to oxidize.)

AVERAGES.

	Number of Determinations.	Average.	Highest.	Lowest.	Difference.
Sample No. 1.					
Moisture,	16	6·21	9·65	5·06	4·59
Soluble phosphoric acid,	21	9·26	9·81	8·77	1·04
Insoluble " "	21	4·75	5·83	4·19	1·64
Total " "	21	17·54	18·30	16·96	1·34
Available " "	21	12·79	13·56	11·42	2·14
Sample No. 2.					
Moisture,	16	9·37	12·55	7·44	5·11
Soluble phosphoric acid,	22	6·46	6·87	5·80	1·07
Insoluble " "	22	·30	2·15	0·87	1·28
Total " "	22	11·40	12·12	10·96	1·16
Available " "	22	10·10	10 37	9·51	0·86
Sample No. 3.					
Moisture,	15	6·15	11·47	4·38	7·09
Soluble phosphoric acid,	22	6·42	7·07	5·83	1·08
Insoluble " "	23	2·94	4·37	2·31	2·06
Total " "	23	12·21	13·40	11·57	1·83
Available " "	23	9·27	9·92	7·20	2·72

1892.

Four Samples Sent Out.

No. 1. Super phosphates containing Keystone (iron and alumina) phosphate.
No. 2. Regular phosphate.
No. 3. Dissolved steamed bones.
No. 4. Thomas slag.

AVERAGES.

	Number of Determinations.	Average.	Highest.	Lowest.	Difference.
Sample No. 1.					
Moisture, ...	22	—	—	—	—
Soluble phosphoric acid, . . .	21	1·92	2·39	1·67	0·72
Insoluble " " . . .	21	7·92	9·21	7·23	1·98
Total " " . . .	23	17·12	17·73	16·27	0·46
Available " " . . .	21	9 20	10·23	7·56	2·77
Sample No. 2.					
Moisture, ...	22	—	—	—	—
Soluble phosphoric acid, . . .	21	2·52	3·10	2·14	0·96
Insoluble " " . . .	21	5·16	5·80	3·37	2·43
Total " " . . .	23	13·95	14·43	13·15	1·28
Available " " . . .	21	8·79	10·58	8·03	2·55
Sample No. 3.					
Moisture, ...	21	—	—	—	—
Soluble phosphoric acid, . . .	21	2·39	2·61	1·75	0·86
Insoluble " " . .	21	8·01	11·15	6·72	4·43
Total " " . . .	23	21·94	22·72	21·22	1·50
Available " " . . .	21	13·93	16·95	11·47	5·48
Sample No. 4.					
Moisture, ...	17	—	—	—	—
Soluble phosphoric acid, . . .	3	—	—	—	—
Insoluble " " . . .	17	11·53	13 28	10·11	3·17
Total " " . . .	17	18·40	19·14	17·69	1·45
Available " " . . .	17	6·87	9·96	4·94	5·02

RECAPITULATION.

Difference in available phosphoric acid in the samples sent out by the association.

1888, ...	1·48	0·71	0·79	—
1889, ...	1·08	1·92	1·38	—
1890, ...	1·00	0·67	—	—
1891, ...	2·14	0·86	2·72	—
1892, ...	2·77	2·55	5·48	5·02

These figures speak for themselves and need no comment of mine. To say that they are satisfactory would be untrue. If you compare the results of the last five years, they apparently show a movement from bad to worse, but this is only apparently.

The samples of the first four years were mainly acid rocks, which are the easiest to handle, while the later reports are

composed of more complicated samples. This is especially the case with the samples of this year. [See full report of Professor Lord, table herewith.]

Sample No. 1 contained considerable Keystone phosphate, an iron alumina high grade phosphate, which has given rise to a great many controversies between chemists.

No. 2 is a regular mixture.

No. 3 is an incompletely dissolved bone, a material which always presents the greatest obstacles to proper filtration.

If you examine the results of No. 3 closely, with differences of over five per cent. available phosphoric acid, you might assume an extraordinary reason. We found in our laboratory that we had to quadruple the filtering paper before we could have a clear ammonia citrate solution, and are satisfied that the main reason for the extraordinary differences lay right there.

Sample No. 4, the Thomas slag, represents a new class of phosphates of lime, a quadribasic phosphate. It will take further study to ascertain if this class of products can be measured with the same rule as the bibasic phosphate in the common run of the fertilizers.

I have to call your attention to the great difference in the determination of moisture:

Sample No. 1.—	Highest,	13·06
	Lowest,	2·76
	Difference,	10·30
Sample No. 2.—	Highest,	20·13
	Lowest,	9·40
	Difference,	10 73
Sample No. 3.—	Highest,	13·53
	Lowest,	5·90
	Difference,	8·63

The absolutely unsatisfactory results of the determination of moisture caused the association to discuss the reason for it at great length, and to the neglect of the main question of the shortcomings in the phosphoric acid determination. The brief time devoted to this year's report was

absorbed without ventilating the serious irregularities in the results obtained on phosphoric acid.

What can be the reason for the utter failure of last year's

[illegible]

Phosphoric acid, ...	2·02	2·24	[illegible]	[illegible]
Total phosphoric acid, ...	15·28	15·66	15·28	15·68

FULL REPORT OF PROFESSOR LORD, COLUMBUS, O., AS GIVEN AT THE LAST MEETING.

Analyst.	Sample No. 1.					Sample No. 2.					Sample No. 3.					Sample No. 4.				
	Moisture.	Water Soluble Acid.	Insoluble.	Total.	Citrate Ammonia Soluble.	Moisture.	Water Soluble.	Insoluble.	Total.	Available.	Moisture.	Water Soluble.	Insoluble.	Total.	Available.	Moisture.	Water Soluble.	Insoluble.	Total.	Citrate Ammonia Soluble.
K. P. McElroy,	7·12	2·06	7·51	16·86	9·35	13·99	2·73	4·55	13·87	9·32	6·90	2·44	4·86	21·81	16·95	0·95	—	8·54	18·50	9·96
A. W. Fries,	3·84	2·11	7·94	17·63	9·69	11·00	2·81	5·52	14·43	8·91	6·43	2·61	11·15	22 62	11·47	0·89	—	11 98	18·61	6·65
H. E. Curtis,	3·41	1.67	9·09	17·65	8·56	9·67	2·14	5·80	14 30	8·50	6·66	2·09	8·95	22·24	13·29	0·94	—	12·25	18·59	6·39
R. E. Noble,	8·79	1·70	7·41	17·12	9·71	16·69	2·41	5·39	14·40	9·01	8·08	2·26	9·50	22 44	12 94	1·46	0·07	10·27	18·54	8·27
S. Shiver,	3·78	—	—	17·24	—	10·05	—	—	13·91	—	—	—	—	21·76	—	0·99	—	—	18·17	—
R. N. Bracket,	—	—	—	17·21	—	—	—	—	13·93	—	—	—	—	21·58	—	—	—	—	18·20	—
J. S. Mong,	7·64	1·94	8·42	17·22	8·80	15·55	2·55	5·05	13·79	8·74	9·07	2·56	10·00	22·00	12·10	1·20	—	13·28	18·22	4·94
T. B. Carpenter,	2·76	1·93	8·13	17·19	9·06	9·43	2·63	5·26	13·78	8·52	5·90	2·46	9·34	22·11	12·77	—	—	12·81	18·26	5·45
R. C. Kedzie,	6·12	1·90	7·48	16·94	9·46	14·47	2·55	5·18	13·81	8·63	7·42	2·52	8·80	21·49	12·69	0·83	—	12·44	18·17	5·73
L. G. Patterson,	3·42	1·79	8·26	17·53	9·27	9·64	2·25	5·67	14·20	8·53	6·40	2·41	5·24	21·93	16·69	0·99	—	10·94	18·37	9 43
W. R. Perkins,	3·39	1 93	8·35	17·55	9·20	9·59	2·28	5·73	14·15	8·42	6·34	2·31	5·55	21·87	16·32	0·89	—	11·07	18·37	7·30
H. Farrington,	3·31	1·92	7·23	16·72	9·49	9·90	2·56	4·89	13·94	9·05	6·55	2·56	6·14	22·03	15 89	—	—	10·11	18·61	8·50
F. W. Morse,	7·27	2·03	8·27	16·88	8·61	14·72	2·92	5·60	14·05	8·45	7·78	1·75	7·93	22·72	14·49	—	—	—	—	—
J. L. Hills,	3·36	1·74	6·81	16·27	9·46	10·76	2·31	4·08	13·15	9·07	6·55	2·07	6·82	20·92	14·10	0·47	0·03	9·97	17·69	7·72
R. J. Davidson,	3·34	1·89	6 66	17·20	10·54	9·69	2·59	5·06	14·04	8·98	6·40	2.49	7·41	22·06	14·65	—	—	12·38	18·34	5·96
J. A. Heberly,	13·06	2·13	8 42	16·76	8·34	20·73	2·80	5·57	13·60	8·03	13·53	2·45	10·39	22·15	11·76	1·54	—	—	18·21	—
C. S. Cathcart,	8·73	1·99	8·93	16·49	7·56	16·05	2·76	5·36	13·98	8·22	7·57	2·46	—	21·22	—	1·19	—	12·75	17·99	5·24
F. J. Fulkenbach,	8·11	1·68	6·64	16·87	10·23	16·05	2·42	3·37	13·95	10·58	7·73	2·23	8·14	21·31	13·17	1·21	—	—	18 62	—
N. W. Lord,	3·47	1·68	7·86	17·14	9·28	10·50	2·27	5·16	14·02	8·66	6·60	2·74	7·17	21·09	14·52	0·93	—	11·09	18·58	7·49
W. B. Viets,	7·80	1·92	7 67	17·00	9·33	15·85	2·68	4·79	13·93	9·14	7·60	2·30	8·69	21·79	13·10	1·22	—	13·10	18·47	5·37
R. B. Moore,	8·42	2·39	9·21	17·42	8·21	14·92	3·10	5·30	13·75	8·45	7·46	1·75	7·93	22·72	14·79	1·18	—	12·13	19·14	7·01
Delaware River Chemical Works,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
F. Bergami,	3·58	2·08	8·32	17·28	8·96	10·00	2·56	5·63	14·00	8·37	6·53	2· 6	10·36	22·40	12·04	—	—	—	—	—
W. J. Williams,	3·10	2·11	7·68	17·73	10·05	9·40	2·75	5·44	14·34	8·89	6·25	2·56	6·72	22.59	15·87	0·75	0·26	10·43	18·82	8·39
Average,	—	1·92	7·92	17·12	9·20	—	2·57	5·16	13·95	8·79	—	2·39	8·01	21·99	13·93	—	—	11·53	18·40	6·87

The column has available phosphoric acid added to it.

absorbed without ventilating the serious irregularities in the results obtained on phosphoric acid.

What can be the reason for the utter failure of last year's researches on phosphoric acid?

The samples sent out by Professor Lord were prepared with the utmost care, which insured absolute uniformity. Should we assume that the balances have not been rightly adjusted? Professor Payne charges manufacturers with using bricks for weights. Have some of the gentlemen made proportionate mistakes in analysis?

The failure to reach closer results in moisture shows very plainly that the necessary care has not been taken in the work, and when in the simplest determination of all analytical work such blunders are possible, we need not wonder at the differences in other more complicated determinations. Analytical work will always bear the stamp of individuality, and no absolute identical results can be obtained, but the differences should not rise above a narrow limit.

The proposition, made at the 1890 session of the society, by Mr. Charles Gibson, of Chicago, to change the official method of phosphoric acid determination by making the ammonia citrate solution slightly alkaline (p. 170), caused me to have a series of researches made in my laboratory to establish to a certainty if such an addition of ammonia would work detrimentally to the interest of acid phosphates derived from lime phosphates.

The result of numerous analyses has clearly demonstrated that it is not possible to show any difference between the results obtained with a neutral solution of citrate of ammonia and a slightly ammoniacal solution.

As an example, I will give only two analyses made with our own acid phosphate:

	Neutral Solution of Citrate of Ammonia.		*Ammoniacal Solution of Citrate, Specific Gravity 1·90, added to 100 cc. Citrate of Ammonia.*	
	No. 1.	*No. 2.*	*No. 1.*	*No. 2.*
Total available phosphoric acid, .	12·66	13·34	12·66	13·51
Phosphoric acid, ...	2·62	2·24	2·62	2·17
Total phosphoric acid, ...	15·28	15·66	15·28	15 68

Sample No. 1 is absolutely identical in its results.

Sample No. 2 shows only a difference of 0·07.

Being satisfied that in the change to a slight ammoniacal solution of citrate of ammonia from the strict neutral no direct harm will be done to the valuation of phosphates derived from phosphates of lime, our curiosity was aroused to see what acidity would show in the same material.

	Sample No. 1. 0·75 *Gramme Citric Acid to* 100 *of Citrate of Ammonia.*	*Sample No. 2.* 1·00 *Gramme Citric Acid to* 100 *of Citrate of Ammonia.*
Total available phosphoric acid,	12·85	13·70
Insoluble phosphoric acid,	2·43	1·98
Total phosphoric acid,	15·28	15·68
Increase of available phosphoric acid,	0·19	0·29

The increase of the available phosphoric acid under such strong acidity as is produced by the addition of 0·75 grm. and 1 grm. citric acid to 100 of the normal citrate of ammonia solution is only 0·19 and 0·29 per centum, a variation which is generally conceded to be permissible in analytical work, as shown by all previous reports of the society, proves to our satisfaction that the claim so often made, that the change of the ammonia citrate solution from neutral to acid causes great differences in the results of phosphoric acid determinations is not borne out by careful researches.

In order to test the stability of the citrate of ammonia solution, my assistant, Mr. Bergami, prepared, October, 1890, a bottle of normal citrate of ammonia solution, which has been kept in one-half litre bottles, glass stoppered, in a closet, and from time to time tested; the last test was made a few months ago, and proved the absolute neutrality of the solution.

In order to prevent the formation of fungus in the solution, we have, during the last few years, added to a quantity of about two litres, 0·1 gramme of salicylic acid. Without impairing the nature of the neutral solution in the least, this minimum quantity has successfully prevented the

formation of the fungus and thereby destroyed the possibility of changing the neutral condition to acidity.

This proves to our satisfaction that the claim of unreliability of the citrate of ammonia solution (p. 179, 180, Rep. of 1890) is not well founded, if all necessary precautions are taken in preparing the solution, and keeping the same in not too large bottles well stoppered, as recommended long ago by Prof. Paul Wagner, of Darmstadt.

The claim, made by the advocates of the ammoniacal citrate of ammonia solution, that the slightest acidity will impair the correctness of the analysis in alumina phosphates or producers, was almost incredible, and the publication of the analysis by Mr. Williams, pp. 178–179 of the last report, proves that the fault must lie somewhere else and not in the normal neutral solution of citrate of ammonia.

There are numerous other points in the determination of available phosphoric acid, which might let in small variations; temperature variations in the water-bath, the washing of the portion insoluble in citrate of ammonia, may influence the results, but I do not hesitate a moment to say that if the official methods were carefully executed by a competent analyst, such discrepancies would not be possible, even in case of iron and alumina phosphate. The Association of Official Agricultural Chemists has given us the very best methods for the investigation of fertilizers—methods that are accepted, with a single exception, over the whole United States (New Jersey alone determines available phosphoric acid at a temperature of 40° C., instead of 65° C., falling thereby one-half per cent. lower in average result). The association has now the imperative duty to establish the fact, that it only needs careful and competent workers to make such results as are laid before you to-night, absolutely impossible.

The fact that differences of two per cent. and six per cent. insoluble phosphoric acid are possible in test samples prepared with care for the very purpose of a trial of methods is calculated to upset all confidence in the so-called control work of the Agricultural Experiment Stations.

The difference in results as shown by the reports on phosphoric acid has very serious consequences for the fertilizer trade at large.

The stations have assumed the roll of arbitrators between buyer and seller. They have gone further, and act as advisers for the farmer by establishing valuations based on chemical analysis.

I will not ventilate to-night the real value of these valuations, but take facts as I find them.

The market valuation as adopted by the Eastern and Middle States is, I believe, seven and one-half or eight cents, per unit available phosphate. Supposing it is eight cents, and take sample No. 3.

The first analyst makes available phosphoric acid

$$\begin{array}{l} 16{\cdot}95 \text{ per cent.} \times 8 \\ \quad 135{\cdot}60 \times 20 \\ \$27{\cdot}12 \text{ valuation per 2,000 pounds.} \end{array}$$

The second analyst makes available phosphoric acid

$$\begin{array}{l} \underline{11{\cdot}47 \times 8} \\ 91{\cdot}76 \times 20 \\ \$18.35 \text{ per ton.} \end{array}$$

Or difference in valuation of $8.67 per ton. On which analysis shall we buy? is a question which readily will come to the farmer.

Supposing Sample No. 3 represents a brand guaranteed thirteen per cent. of available phosphoric acid.

In several Southern States a falling off of ten per cent. of the guaranteed analysis makes the goods liable to confiscation.

In this case two analyses of State chemists, the second and sixteenth, will brand the goods as to be condemned under the law. But if the manufacturer should have been misled by one of the numerous high results, and put his guarantee high, he made himself a criminal in half the States of which you have the returns before you.

As long as the results of chemical analysis are so uncertain, as shown by the work of the official association

under the most favorable examination, the public should be extremely careful in forming judgment on a single report of a station if the same should show a remarkable difference between guaranty and results.

The fertilizer trade has been maltreated by suspicion, perhaps, more than any other trade. The trade has been surrounded by an endless chain of different State laws; some of which are in conflict with the Constitution of the United States, and these laws are, to a great extent, based on the idea of the infallibility of chemical control. How infallible the States' control can be, I have shown you to-night by the work presented.

The work of the Association of Agricultural Chemists deserves to be highly commended for the good it has done, but the association must go further, before it can hope to be recognized as the arbitrator in the fertilizer trade.

The association should influence State legislation through its members, to the end that the laws regulating the trade shall be made to conform with the practical results of their work.

The influence of the association should be exerted likewise in the legislation of New Jersey, to effect the repeal of an antiquated dictum in analytical work erroneously sanctioned by law; and in the Southern States, where unjust laws have been based on the belief in the infallibility of control work of the agricultural station.

DISCUSSION.

DR. WM. J. WILLIAMS.—I have listened with much pleasure to Dr. Terne's paper on the discrepancies found in the analyses of different official chemists when engaged in analyzing the same goods, and not merely the same goods, but actually the same (divided) sample of the same goods.

Dr. Terne has called attention more particularly to the analyses of bone—raw and partially dissolved. Similar cases have arisen in my experience, with even greater discrepancies in dealing with our Keystone concentrated phosphate, a concentrated phosphate of iron and alumina. While several chemists of high standing in the profession,

both official and non-official chemists, gave the quantity of available phosphoric acid fairly closely, as, for instance:

Per Cent.	*Per Cent.*
30·60	30·25
30·87	30·35
31·02	30·37
32·35	

others could only get 25·22 per cent. and others 20·31, 19·40 and 19·70 per cent. The last three especially show a difference beyond any reasonable limit.

Now, as the verdict of an "official" chemist is final in his State, or at any rate his figures are published and become generally known, such discrepancies work great injustice to manufacturers, and if the official chemists could make some change in the "official" method, whereby these discrepancies could be minimized, it would be a great advantage to all concerned.

The question has already been discussed by the official chemists in convention, but up to this time no solution of the difficulty has been arrived at.

One point suggested was that a slight acidity or alkalinity of the "official" neutral ammonium citrate solution caused the greater part of these differences. So far as my own investigations go (made since the convention above referred to), I do *not* find that a *slight* acidity or alkalinity of the solution makes any appreciable difference greater than the ordinary errors of analysis.

I find, however, that a slight difference in the time of exposure of the material at 65° C. does make considerable differences in the results. The instructions now given read: "Cork the flask securely and place it in a water-bath, the water of which stands at 65° C. * * * Raising the temperature as rapidly as practicable to 65° C., which is subsequently maintained, digest for *thirty* minutes *from the instant of insertion*," etc. Up to 1887, I think, or possibly 1888, the instructions were to this effect: Place the flask in a water-bath, the temperature of the water in which is 65° C., raise the contents of the flask up to 65° C. as rapidly as possible, and *maintain at that temperature* for thirty minutes. (I cannot

give at the moment the exact words, but that is the substance.)

Now, it would appear that this difference of instructions should not be of much moment, as all using the official method are working under the same instructions, and in all cases the time of exposure to a temperature of 65° C. is of equal duration, but such is not actually the case. Under the earlier instructions the contents of the flask were uniformily exposed to a temperature of 65° C. for thirty minutes; and under these conditions these great discrepancies in results appeared neither so frequently nor to so great an extent. But when the instructions were changed to the present form, viz: "Digest for thirty minutes from the instant of insertion," then they became greater and more frequent.

This, I think, is due to the differences in the conditions to which the material is exposed in the water-bath; that is to say, the solution of exposed neutral ammonium citrate reaches 65° C. much quicker in some cases than others. I made inquiries from many chemists on this point, *i. e.*, how long it required for the solution in the flasks to reach the temperature of 65° C. after insertion in the water-bath. The time varied from three to nine or ten minutes. That is to say, the time during which the material was exposed to a temperature of 65° C. varied from twenty to twenty-seven minutes, a variation which is, I believe, sufficient to account for the greater part of the discrepancies. This variation in time can be ascribed to many causes, *e. g.*, size of bath, depth of water, quantity of heat used, thickness or shape of flasks or other vessel, etc., and it would appear impossible to produce uniformity of conditions, and, therefore, uniformity of results under the present directions. I think, however, if the instructions were modified, so as to secure the exposure of the material to a temperature of 65° C. for a uniform fixed time of thirty minutes, as was done under the original form of instructions, instead of to a variable time ranging from twenty to twenty-seven minutes, as under the present form of instructions, that the results would be far more uniform and would be far more satisfactory to all concerned.

OBSERVATIONS ON FERRO-TUNGSTEN.

BY WM H. WAHL.

[*Read at the stated meeting of the Chemical Section, held November 15, 1892.*]

In the course of an investigation carried on during the past two years by the writer, in conjunction with Dr. William H. Greene, with the object in view of producing pure ferro-alloys, we made a number of experiments with ferro-tungsten.

These tungsten alloys exhibited similar physical properties possessing considerable hardness and toughness, an extremely fine crystalline texture, with a fracture resembling that of tool-steel, and a specific gravity ranging between 9·3 and 10·14.

Some of the fractures, however, exhibited the fact that the alloy was not entirely homogeneous, disclosing under the glass and in places to the eye, the presence of what are apparently smooth cleavages of imperfect crystals scattered through the finely-crystalline matrix of the alloy. The specimen shown you will illustrate my statement.

A sample of the alloy of 10·14 specific gravity was analyzed at my suggestion, by Mr. J. F. de Benneville in the laboratory of Dr. Genth. The result of the analysis exhibited a very high percentage of tungsten in the sample, and its behavior towards liquid and fused solvents proved the interesting fact that a large proportion of the tungsten was present in the uncombined condition, as metallic tungsten, crystallized in the matrix of the alloy. The facts upon which Mr. de Benneville has founded this observation will appear in the following extract from a letter describing briefly the method pursued in his analytical work.

"*Aqua regia* attacked it, although not energetically, and by decanting and adding fresh portions of acid from time to time a residue was obtained which resisted further action by acids, or by fusion with Na_2CO_3 and KNO_3. It was a heavy, black, pulverulent substance, and in its negative

action towards solvents answered to tungsten, which I took it to be. It gave 22·54 per cent. of the original material. A second portion of the material (powdered in a steel mortar) was fused with a mixture of Na_2CO_3 and KNO_3, lixiviated and the residue weighed. This was fused again and the residue weighed, the second weighing being practically the same, and yielding 22·80 per cent. of the original material, using strong HCl (1·20 Sp. gr.) in successive portions, decanting, igniting the residue and treating again with acid, gave me 21·74 per cent."

The foregoing extract appears fully to justify the conclusion that the undissolved residue represents the metallic tungsten present in the alloy in the uncombined state.

The composition of the metal analyzed by Mr. de Benneville is as follows:

	Per Cent.
C, ...	0·85
P, ...	0·041
Si, ...	0·14
Mn, ...	trace
Fe, ...	42·28
W (metal), ...	22·54
W (alloy), ...	34·35
	100·201

A study of these figures reveals another interesting fact to which I desire to call your attention.

Taking the figures of the iron and combined tungsten (42·28 : 34·35) and calculating the percentage of tungsten which this ratio represents, we obtain 44·82 per cent. tungsten. A calculation shows also that the figures representing the compound Fe_4W are almost identical with the ratio above-named, to-wit:

Fe_4W Found.	Fe_4W By Theory.	Difference.
Fe, 55·18 per cent.	Fe, 54·91 per cent.	
W, 44·82 "	W, 45·09 "	— 0·27
100·00	100·00	

The conclusion would seem to be justified by the facts above noted, that the saturation point of iron for tungsten

is represented by the ratio exhibited in the compound Fe_4W, and that any excess of tungsten, above this ratio, present in a tungsten iron will remain uncombined.

I wish to express this statement as *probably* the correct interpretation of the facts, for it is hazardous to make a generalization of this kind on the results of a single analysis.

It may be interesting to note in conclusion that Howe, in his "Metallurgy of Steel," refers to several cases of ferro-tungsten indicating the composition Fe_5W, and that the works on metallurgy as a rule accept without question the dictum that iron and tungsten will unite in all proportions. In the light of the facts given in this paper, this last statement requires qualification.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, October 25, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 25, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, thirty-four members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and clerical work, which were approved and ordered paid.

The Committee on Admissions reported ten elections to membership since last meeting. Two nominations were referred to this committee.

The first sentence of Article IV of the Section's By-Laws was amended to read, "The annual dues of active, corresponding and associate members shall be two dollars, payable annually in advance, on the first of January of each year."

Mr. Elmer G. Willyoung exhibited "A New Ballistic Galvanometer," and read a paper describing it. The instrument is made by Queen & Co., its principal features being the composite coils consisting of about five different sizes of wire forming portions of the coils, whose shapes are obtained by careful calculation for best effect; the magnetic system consisting of four bell magnets, the lowest one carrying a movable ring, by means of which the sensibility of the system can be varied without using a controlling magnet; and the quartz fibre suspension. The paper was referred for publication.

Mr. Paul A. Winand read a paper "On the Measurement of Energy in the Three-Phase System," in which he described the best methods of obtaining correct results. Referred for publication.

A communication was read from Mr. E. G. Willyoung inviting the Section to visit the Electrical Laboratory of Queen & Co., at Ardmore, Pa., and upon motion the chair appointed Messrs. E. A. Partridge and Rondinella a committee to make the necessary arrangements.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

A NEW BALLISTIC GALVANOMETER.

(*a*) WITH HIGH INSULATION, GRADED COILS, AND OTHERWISE CONSTRUCTED CLOSELY TO THEORY.

(*b*) WITH A NEW METHOD OF VARYING THE SENSIBILITY WITHIN THE WIDEST LIMITS WITHOUT THE USE OF A CONTROL MAGNET.

BY ELMER G. WILLYOUNG.

[*Read at the stated meeting of the Electrical Section, Tuesday, October 25, 1892.*]

(*a*) The galvanometer which I am about to present to your notice is not, as are many instruments, the result of chance development, but represents the fulfilment of deliberate intention aided by close application of theory and experimental data systematically obtained for the purpose. Some six or eight months ago it became necessary for the firm with which I am connected to place upon the market a good ballistic galvanometer, and I accordingly set about to design and build such an instrument. After a little time spent in looking over a number of combinations and general styles advocated by various persons, and in pondering different theoretical considerations, I designed an instrument somewhat similar to that which you see. (*Fig. 1.*) This first instrument, when completed, was taken in hand at the laboratory and thoroughly tested under a large variety of conditions: its law of deflection, its leakage, the decrements of damping with coil frames open and closed; with coils short-circuited, and in series with various resistances, were all found.

Various modes of suspension and of constructing systems were also tried. In particular, a considerable time was devoted to a study of different methods of varying the sensibility of the system and some important conclusions were drawn. After this earlier and systematic study of the instrument it was placed in the laboratory, and used for the

regular daily work of determining battery curves, condenser capacities, making hysteresis determinations, etc., which naturally make up the routine of a working laboratory. After some weeks of work of this kind and accompanying "unconscious cerebration" of the writer, and of one of his associates, Mr. Northrup, who made most of the systematic tests first referred to, the matter was again taken up, a modified design produced, and the instrument constructed which you see here. I will first refer to more general points which are to be noticed.

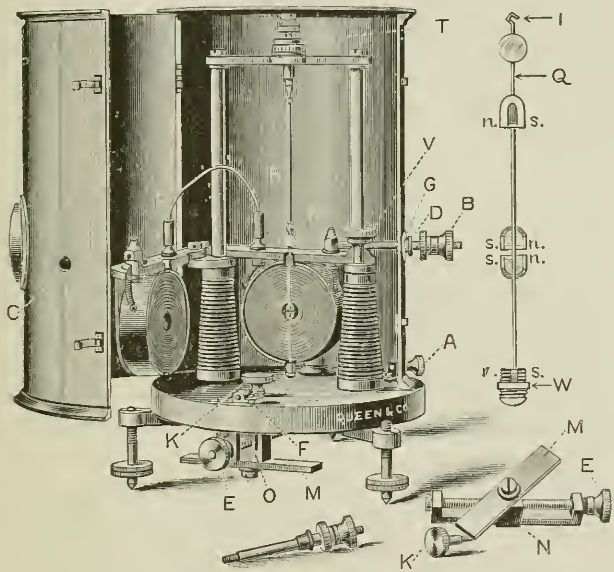

FIG. 1.

To speak of the general plan of the instrument for a moment, the coils are two in number and equal in size; they close upon the magnetic system, which hangs in a diameter between them, and are supported upon highly polished and corrugated hard rubber pillars. These pillars are two and seven-sixteenths inches high, and, since the corrugations are sides of equilateral triangles, they are equivalent to plain pillars of just twice the surface or about five inches high. The surface resistance to leakage is, therefore, very great. Upon the rubber pillars are brass rods joined at the top by

a cross bar, which carries the torsion head and its suspension. The suspension is, when in position, a trifle over two and three-fourths inches long. The torsion head is divided into 15° divisions, and by its means the coëfficient of torsion of any suspension may be quickly obtained. I want to call particular attention to the coils of this galvanometer; in this regard the instrument has been as closely conformed to theory as possible. It is, of course, a fundamental fact of galvanometer theory that the electro-magnetic effect of a coil upon a magnet is directly proportional to the number of turns in the coil, and hence, in a very sensitive instrument, the windings must be as many as possible; a moment's thought, however, makes it clear that there is a practical limit to the number of turns which may be used, and that this limit is reached when the coil has obtained such a diameter that the loss of electro-magnetic action due to increased resistance is equal to the gain effected by the extra turn. In this we are assuming that but one size of wire is used in the winding; if now we increase the cross-section of the wire suitably we may still increase efficiency by adding turns, and this to an indefinite extent by continuing to increase the cross-section as a function of the increased diameter; by doing this, however, the coil would soon become of unmanageable proportions. It can also easily be shown that the exterior bounding surface of a galvanometer coil, for maximum effect, is a surface of revolution the equation of whose meridional section is $u^2 = c^2 \sin \theta$ where c is a constant.* The form of this curve is shown in *Fig. 2*, which represents a meridional cross-section of a properly-shaped coil, where there are several curves based on different values of c. It is obviously not commercially possible to vary the wire as continuously as rigid conformity to theory would require, as this would mean a continuous wire tapering uniformly from one end to the other; instead of this we may, however, obtain an approximation to theory by changing the sizes of wire used a greater or less number of times. This is what

* Maxwell's *Elec. and Magnetism*, Vol. ii, p. 361 (3d ed.).

has been done in the coils before you,* and, indeed, is what is being done now in all galvanometers made by our firm. The usual number of changes which we make is five, and that number has been employed here. Galvanometer coils wound in this way are called "graded" coils. In effecting this grading we first decide upon the total resistance of the coil and then by an application of the mathematical theory, as given in Maxwell, determine the exact diameters of the wires which must be used and the positions and shapes of their bounding surfaces, the latter, of course, satisfying the equation $u^2 = c^2 \sin \theta$. The labor involved in making these calculations is considerable, as the insulation thickness of the wire is a complicating factor which must be allowed for; it is, in fact, necessary to obtain the final result by a series of approximations of at least three in number, first substituting an approximate value of δ, the ratio of insulation thickness to the radius of the bare wire, from which we obtain an approximate value of this bare wire radius; we then substitute a more correct value of δ and solve again and at last use the nearest gauge number to the obtained diameter. We do not, of course, work all these calculations out every time we wind a pair of coils, as that would not be commercially possible. Our coils on all our galvanometers are of the same size, or rather are reduced to several standard sizes and gauges are used for each size. Consequently we have been enabled to work out the complete winding for each size of coil for every resistance likely to be desired from one-half ohm to 10,000 ohms; we have a typical drawing, properly lettered, and all that is done is to wind wire until the bounding curve of the wire surface calipers to the determined data.† I have here (*Fig. 3*) one of the forms upon which the coils are wound. We have a number of these for each of the two or three types of coils, all of each type being rigidly the same size. They are made so that after a coil is wound the sides and core can readily

* A specimen coil, wound and ready to slip into any galvanometer frame, was here shown.

† This typical drawing was here shown together with the table of calculated data accompanying it from which coils are actually wound.

be slipped away. The core is of steel, in order that it may be very small and yet be of sufficient strength. Note the peculiar curve (*A*, *Fig. 3*) at one side; this is a mathematically determined curve, and is so shaped as to secure the maximum action upon the needle of the windings lying close to the magnets. Here is a wound coil ready for slipping into the frame; I think you can all see the lines of separation of the various windings, and that they have a greater diameter upon the one side than upon the other. In the pair of coils used in this instrument the space surrounding the magnets has been made very small, so as to make use of the exceedingly valuable space lying close to the centre. To show the practical advantage of grading coils, if the coils of this

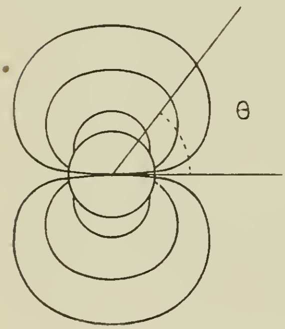

FIG. 2.

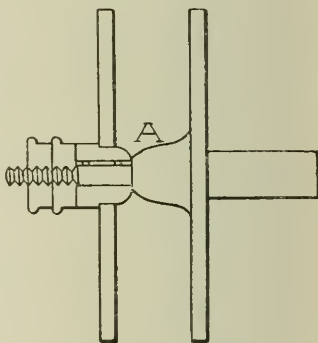

FIG. 3.

galvanometer had been wound to the same resistance with but *one* size of wire, and occupying the same volume, the sensibility would have been but four-ninths as much. The difference in cost is very inconsiderable.

The clearance between the coils in this instrument is but one-twentieth of an inch, leaving only just enough room for the shaft of the system to work freely. The coils may be used in any way desired, either singly or in series or in multiple, thus giving one three instruments in one, *e. g.*, the present instrument is of about 5,000 ohms resistance with the coils in series; using either coil singly the resistance is 2,500 ohms and in multiple 1,250 ohms. The various connections are quickly made by means of the

little plug tipped flexible cords (*R*, *Fig. 1*), which plug into little receptacles *P* on the coil frames. In case a greater range even than this is desired, the coils are made interchangeable and may readily be removed from the instrument by simply loosening one screw on each frame. The binding posts *B* are placed at the extremities of brass rods which pass through the case and screw upon lugs attached to the coil frames; where the rods pass through the case, the case holes *G* are bored somewhat larger and a rubber collar *D* fits upon the rod and fills up the holes in the case, keeping out dust and dirt; when the instrument is to be used the collars are drawn back so that there is no possibility of leakage taking place through the case, and the entire instrument is still supported by the corrugated rubber pillars.

It will be noticed that there are no levels upon this instrument; they are left off purposely. I don't know that I had ever seen a good galvanometer without levels attached until I began to leave them off of our instruments. I had never questioned the utility of them while I was simply a user of apparatus, although I never made any use of them myself, but when it became a matter of business and my attention had to be given to the subject of designing the best for the lowest cost, I soon came to look upon the level as an utterly superfluous appendage. Theoretically, of course, the level has been upon the instruments for the purpose of adjusting them *to* the system, so that when the bubble was in its proper position the system would hang perfectly free; practically, however, the clearance allowed in a good galvanometer is so small that the slightest lack of perfection in the adjustment or change of position of the torsion head would cause the system to stick; the smallest hair or shred of insulating material or stray fibre would operate in the same way, so that actually the user has always found it far more convenient to level the instrument up by means of the levelling screws, until, by observing the mirror, the system was seen to swing free. If this was not easily attained the coils would be swung apart, and the system and faces of the coils closely inspected to ascertain the

cause of difficulty. I have inquired of many experienced users of these delicate galvanometers, and have always received the same reply, viz: that they never thought of using the levels and found them entirely unnecessary, thus confirming my own experience. In order quickly to inspect the system, the coils are pivoted so as to be easily thrown open by merely removing the binding post rods and raising

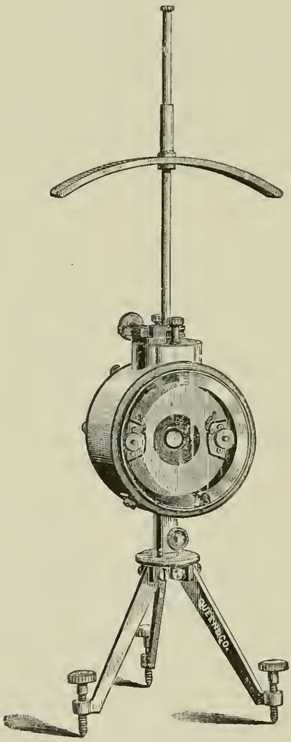

FIG. 4.

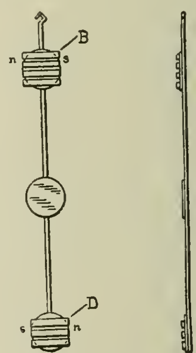

FIG. 5.

the milled screw clamp V. In practice the first coil only is swung away.

(*b*) Having thus described the more general characteristics of the instrument, I want to speak more particularly of an improvement in galvanometers having moving systems composed of magnets which has been devised in our laboratory and applied for the first time in this form of instru-

ment. The improvement consists in a means of varying the sensibility of the instrument within the widest limits in an exceedingly simple way, and in a manner which entirely does away with some of the annoying inconveniences and sources of inaccuracy which have been experienced heretofore when using instruments of this character. The usual method of varying the sensibility of galvanometers of this kind has been, as is well known, by neutralizing to a greater or less degree, the influence of the earth's field upon the system by means of a control magnet suitably placed upon the instrument. This magnet has usually been placed upon a standard attached to the instrument and rising from its centre above as in the galvanometer shown in *Fig. 4*. Occasionally this magnet has been placed below instead of above, and in one or two patterns at the front or back. This magnet could be raised or lowered to change the intensity of its field at the needle, or oriented, in order to change its plane; occasionally, also, a means of changing the intensity of the control or its plane without moving it to or away from the needle has been employed.* All these plans have been somewhat expensive to use, and all, except the last, have been open to the objection that they could not be used without jarring and disturbing the instrument. But the most serious difficulty has been due to an entirely different cause, which I will endeavor to point out. Let us conceive of the case of a system composed of two sets of magnets, *B* and *D*, *Fig. 5*, the upper set composed of four magnets with their north poles pointing in one direction, and the lower set composed of three magnets of the same length as the upper set, and with their north poles pointing in the opposite direction; this combination is known as an "astatic" system, since the controlling force of the earth's field is only the *difference* of the magnetic moments of the two systems. In the case supposed, the upper set "controls," and the north poles of the upper system will point to the north. If now we wish to make the system still more astatic we weaken the earth's field upon the upper needle by means of

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* See Kittler's *Handbuch der Elektrotechnik*, pp. 226, 227, 228, Vol. i, 1886.

a control magnet suitably placed near it.* We now have the magnetic system subject to the influence of two fields, one the earth's and the other the field of the control magnet. We may represent these two fields in strength and direction by lines suitably drawn; let us also suppose that these fields are placed to oppose one another, but with planes not rigidly parallel. *Fig. 6* (*a*) shows this with *A B* representing the earth's field in strength and direction, and *A C* that of the control magnet. Completing the parallelogram we obtain *A D*, which represents the resultant field in direction and intensity. Let us suppose, now, that the earth's field slightly changes in direction, as is shown in (*b*) *Fig. 6.* The resultant now point, nearly directly opposite to its first position, and though the earth's field has moved through but an exceedingly small angle, we see that the resultant

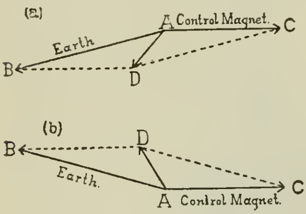

FIG. 6.

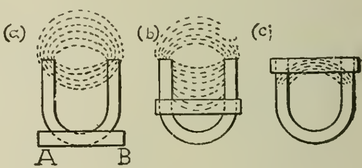

FIG. 7.

will have moved through nearly 180°, so that the slightest shifting of the earth's meridian causes an immensely magnified movement of the resultant. This theoretical conclusion is thoroughly realized in practice, although but few who are annoyed by it are aware of its cause. It is, of course, seen that this magnification varies with the sensibility and is largest when the instrument is most sensitive. In galvanometer work this phenomenon is known as the "drift" of the needles, and the tyro in galvanometer practice is very apt to think his instrument bewitched for some time after

* This is the method which has always been employed in instruments which have been used; it is, however, not theoretically the best way, which would be to place a standard at right angles to the earth's meridian and midway between the sets of magnets, and place upon this standard a control magnet, rotating upon it in a plane at right angles to the standard; its horizontal component would vary with its phase.

making its acquaintance. There are none of us, probably but who have experienced it; we work at an instrument, adjust the telescope and get the mirror nicely on zero. In a few minutes we look again and find some other number of the scale before us, and if we watch for a time, we may see the scale travelling along the mirror, until often it disappears entirely, the mirror having entirely left it; if we let it alone it will very likely come back later in the day and go in the other direction. The mirror is never still, going now one way and now another, though more stable during some parts of the day than at others. This is apt to be a very serious hindrance in making exact observations when the instrument is very sensitive, as when the mirror fails to return to zero after a deflection we are unable to tell definitely whether this is due to the cause just mentioned or to some other, and, if the former, as to just how much must be added to or subtracted from the observed deflection on this account. It also necessitates frequent re-adjustment and hence, re-determination of the constant of the instrument to prevent the mirror going entirely off the scale. I will now explain the improvement embodied in this instrument, and now for the first time made public. The device is the invention of Mr. E. F. Northrup, of Queen & Co.'s laboratory, and I regard it as one of the most important additions to galvanometer practice which has been made for many years. By its use all the annoyances of "drift" are eliminated and the instrument rendered much more certain in its indications besides being less costly to manufacture. Reference to *Fig.* 7 will show the principle of the device; *M* is an ordinary horseshoe magnet at the bend of which is a bar of soft iron *A B*; the distribution of the lines of force is practically unaltered by this bar. In (*b*) we have the same magnet, but with the bar moved about half-way up towards the poles; the lines of force are now considerably deformed, and many have been drawn down so as to pass through the soft iron armature. In (*c*) the armature has been pushed up to the very poles, and almost all the lines are now passing through it, the magnet thus being short-circuited and made about as ineffective, as regards its exter-

nal field, as would be a mass of soft iron of the same shape. Now, let us look at *Fig. 8*, which represents the system used in this instrument. The system is seen to be composed of four "bell" magnets of the well-known Siemens type; the upper and lower have their poles turned in the same direction while the centre magnets have their poles also in the same direction but opposite to that of the outside magnets. The upper and lower magnets thus make up one set of an ordinary astatic system, and correspond with

FIG. 8.

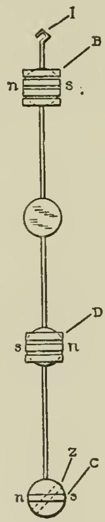

FIG. 9.

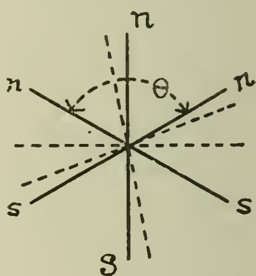

FIG. 10.

the set *B*, *Fig. 5*, while the centre magnets correspond with the set *D*. The outside magnets are, as will be noticed, slightly longer than the inner ones, and will, consequently, if all are magnetized in practically the same way, be the stronger, and will "control" the system. If now we weaken one or both of these outside magnets their control will be lessened, and the period of the system will be increased, until finally the influence of the inner magnets will begin to predominate, and the system will swing round through 180°. The means by which this weakening

is accomplished are in this instrument very simple. The lower magnet has cut upon it a very fine screw thread, and upon this thread is fitted a narrow and light ring of soft iron *W*. When the ring is at the bottom of the magnet its influence is *nil;* if we desire a greater sensibility we simply screw the ring up until this sensibility is attained. In order to do this easily, the system is attached to the fibre by means of an exceedingly small hook *I*, and may readily be removed by simply lifting it off with the aid of a small pair of forceps when the ring may be moved a trifle, the system replaced and the vibration period observed. In practice all this can be done in a very few minutes. It might be objected that in thus "short-circuiting" this outside magnet we lose a portion of the deflecting moment of this magnet, which is, of course, acted upon by the coil. This is true but the loss is very small, the effective couple of these outside magnets being vastly less than that of the inner. The best proof, however, is the result, and here are some of the results obtained with this instrument. Using the old method of control, *i. e.*, an exterior control magnet, we had:

Period (single swing), ...	$4\frac{17}{25}$ seconds.
Mean deflection $\frac{1}{5}$ M. F. at 1·44 volts, ...	100 mms.
Drift in 5 minutes, ...	2·5 mms.

With Northrup's method:

Period (single swing), ...	$11\frac{1}{10}$ seconds
Mean deflection $\frac{1}{5}$ M. F. at 1·44 volts, ...	211·5 mms.
Drift in 5 minutes, ...	Inappreciable.

And making still more astatic:

Period (single swing), ...	21·6 seconds.
Mean deflection $\frac{1}{10}$ M. F. at 1·44 volts, ...	237 mms.
Drift in 5 minutes, ...	Inappreciable.

The large vibration period of over forty seconds for a complete swing obtained without "drift" is extraordinary in my experience; it may readily be made much greater, however, and the instrument correspondingly more sensitive if desired by this method. I have here a system made in the same way as the one in the instrument before you, but larger, so that I may illustrate the working of this

device. It is hung by a silk fibre with the short-circuiting ring at the bottom, and the system is as insensitive as it can be made with the outside magnets controlling. I start it vibrating, and we note that the period is very short, something like three seconds (*s. v.*). I now screw up the ring about four turns and you will notice that the period is considerably lengthened and is now about ten seconds (*s. v*). Now, it is about twenty seconds (*s. v.*), and by screwing it up further I can completely reverse the plane of the system; if I continue to still further weaken the lower magnet I shall obviously make the system less and less sensitive, since the centre magnets will control more and more strongly. Instead of screwing this ring on we may, of course, merely slip it on, allowing it to hold by its own friction only. We may also apply it to the upper instead of the lower magnet, or to both if we desire. The application of this same method to the orthodox light system is obvious and may be made in a variety of ways. *Fig. 5* represents in diagram such a system as used in the Thomson four-coil galvanometer as made by us, and *Fig. 9* the system as it might be modified to use Northrup's device. Here there are two sets of magnets, *B* and *D*, which would lie in the centre of the upper and lower pair of coils, respectively.

To use the new device we make the shaft of the system long enough to extend down a little below the bottom of the lower coil and place upon it an extra magnet *C*, as shown in the figure, with its poles placed in the same direction as those of the upper set. At the back of this little extra magnet we pivot a small piece of soft iron *Z*, of about the same size and shape as the magnet, so that it may be rotated to be either perpendicular or parallel to it. When in the former position, the little extra magnet is allowed to assist the upper set which consequently controls; when in the latter, the extra magnet is short-circuited, and the influence of the lower set of magnets, being a trifle longer, predominates. The weight added to the system by this construction may be so small as to be inappreciable in all except the most delicate instruments. We ourselves, however, have not yet adopted this device as applied to very light and small

systems, on account of the excessive delicacy of construction involved and of lack of time in which to work this out with thoroughness. The necessary delicacy of such a "light" system is so very great,* mechanically, that I have doubts as to whether the device had best be applied to such. In the instrument before you, I use an exterior control magnet when the light system is used. This magnet you see in position upon the base (*Fig. 1*); a middle head *E* works a screw through a block *O*, so that the position of the magnet with reference to the system is easily varied. When the ballistic system is used, this magnet is easily removed by unscrewing the small head *K* upon the upper part of the base.

The general construction of the system used in this instrument is well worth looking at, as considerable pains have been taken to work out one thoroughly adapted to the requirements. As is well known, a perfect ballistic system must have so large a moment of inertia that the entire quantity of electricity which it is designed to measure must have time to pass through the coils before the system is able to move. In addition it must be so shaped as to have a minimum damping either of air friction or magnetic or otherwise. To avoid air friction, the system must be of small diameter and shaped so as not to scoop and carry air before it and it must be very heavy in order to give it the required large moment of inertia. This system, I think, thoroughly conforms to all the requirements. The magnets are cylindrical bell-shaped magnets of but thirteen-sixty-fourths inches in diameter and are threaded upon a shaft of quartz rod; in order to make them very heavy they are filled with small fragments of lead, held in place by means of a little hard wax; after being filled thus a little brass washer is placed in the end of each magnet with the shaft passing directly through its centre; this is for the purpose of holding the magnets in place in a perfectly symmetrical manner. The whole weight of this system is 4·5 grammes. It is

* A light system, as made by us for Thomson reflecting galvanometers, weighs somewhat less than 350 milligrammes.

made with a small hook, *l*, above, so that it can be quickly unhooked from the fibre for adjustment or to be replaced by another kind of system. The fibre also hooks into place and can be quickly removed in correspondence with the system which is to be used. For the most delicate work the use of hooks introduces a slight error as the two hooks will "ride" upon one another through a very small angle and thus the system will deflect without torsion of the suspension. In such cases a small drop of hot beeswax touched to the hooks will cement them together in a perfectly satisfactory manner, and they are readily separable again by touching for an instant with a warm iron or brass wire.

The suspension itself of quartz and is about $\frac{7}{10000}$ of an inch in diameter; quartz is used because it has absolutely no set whatever, a statement which is true of no other suspension, metallic or otherwise, of which I have knowledge, its elasticity is almost perfect through extremely large limits. According to Professor Threlfall a quartz fibre will stand one-third of a turn for every one-half inch in a fibre $\frac{4}{10000}$ inch in diameter. It is also unaffected by ordinary atmospheric or temperature changes, and has so great a tensile strength that, for the same system, its coëfficient of torsion will be less than that of the finest silk fibre. We are able now to draw these fibres out to any length and to any degree of fineness with great facility. You may wonder how the hooks are placed upon the fibre: by simply platinizing the ends and soldering the hooks to them. When we first established our laboratory at Ardmore, all the suspensions of all our galvanometers on this general type were of silk; now I doubt whether a silk fibre can be found anywhere, all are either quartz or metallic. Some of these fibres have been made and are occasionally used for the most delicate suspensions, so fine that it has been impossible to see them except by the interference colors which are produced; to the eye there is a flash of beautiful iridescence, nothing more. Their tensile strength is very great, over 150,000 pounds to the square inch in the finer sizes. I made mention of the fact that the magnets of the system are threaded upon a quartz rod; there is a reason for this also, which we have

discovered, and which, as far as I know, has not been thought of by others. It is simply this: any wire, during drawing, is put under mechanical strain and forced into a certain condition which will gradually work itself out. The resistance of wires of all kinds is greater immediately after drawing than it will be a little later, speaking, of course, with reference purely to mechanical changes and not to chemical ones. The wire is hardened by drawing and slowly anneals by contact with ordinary atmospheric temperatures. The same is true of glass as is well illustrated by the changes which take place in thermometers after they have first been made, unless the glass used has been kept in the tube form for a great length of time. Good thermometer makers consider it necessary to hold glass for several years before being used, if the thermometers are to be really standard. All this is not true, however, of quartz, and if it were possible to obtain quartz in the right shape or to get it into that shape and work it, we should be able to make thermometers almost absolutely correct and which would remain so. Now, let us again look at the system shown in *Fig. 5*. Here there are two sets of magnets, or, essentially, two magnets, with their poles in opposite directions. Let *Fig. 10* represent, diagramatically, these two magnets opposed to one another but not quite in the same plane. These two magnets are evidently equivalent to another magnet whose plane will be somewhere in the angle θ; let us suppose that it lies in the position indicated by the dotted line; this dotted line will, therefore, lie in the plane of the earth's meridian, assuming for convenience that no other field but that of the earth is operative. If, now, either of the magnets shifts its plane with reference to the other there will be a corresponding shifting of the resultant plane or the *system* will rotate until the *new* plane is in the earth's meridian. We will, therefore, have "drift" again but due to another cause. If we use aluminum or other metal wire the twist produced by the original drawing of the wire will slowly work itself out, perhaps taking months to do so, and we will always be more or less bothered by the consequent drift. Glass is equally bad as metal. Quartz, however, will not alter and is perfect

for this purpose. To prove our hypothesis we took aluminum wire upon which was a system, and in which there was but little drift, and gave the wire a slight twist; drift invariably followed and in the direction which theory would lead us to expect from the direction of twisting.

BOOK NOTICES.

Recent Progress in Electric Railways: being a summary of current periodical literature relating to electric railway construction, operation, systems, machinery, appliances, etc. Compiled by Carl Hering. New York: The W. J. Johnston Company, Limited, 167–176 *Times* Building. London: Whittaker & Co., Paternoster Square. 1892. Price, $1.

The publishers of *The Electrical World* contemplate the publication, from time to time, of a series of small volumes embracing a review or summary of current progress in the various branches of applied electricity, in which form the labor of search through the voluminous and inconvenient files of the electrical journals in which this information is now scattered will be avoided. Such a digest of information, prepared by skilful and discriminating compilers, should be of substantial benefit to active workers in the great electrical field, who would duly appreciate the saving of time and labor which it would mean to them. The volume above entitled is the first of the promised series, and forms a useful *résumé* of the subject of the electric railway, historical, statistical and technical. J. C.

Questions and Answers about Electricity. A first-book for students, etc. Authors: T. O'Connor Sloane, A.M., E.M., Ph.D., Caryl D. Haskins, M.I.E.E.; A. E. Watson; Edw. Trevert. Illustrated. New York: D. Van Nostrand Company. 1892.

This volume forms a 16mo of 100 pages, and is intended for the special service of the beginner. It is written in the style of a catechism, and covers the following chapter heads: "Theory of Electricity," "Theory of Magnetism," "Voltaic Batteries," "Dynamos and Motors," "Electric Lamps," "Electrical Appliances," "Electrical Measurement," and a "Glossary of Electrical Terms." The work of the authors appears to have been well done, and the book should prove extremely useful to the class for whom it is intended. J. C.

Encyclopêdie Scientifique des Aide-Memoire, publiée sous la direction de M. H. Léauté, Membre de l'Institut. Paris: Gauthier-Villars et Fils et G. Masson. Libraires-Editeurs.

The scheme of the publishers in the announcement of this work contemplates the publication of about 300 volumes, in small 8vo form, to appear at the rate of about thirty or forty volumes per year. Each of these is

designed to be strictly practical in its character, and to represent at the hands of a distinguished expert the state of the art to which it relates. It will embrace the entire domain of the applied sciences—engineering, mechanics, electricity, physics, chemistry in one series, and agriculture, biology, medicine, surgery and hygiene in another. Each volume will be signed with the name of its author.

The following volumes of the mechanical, physical and chemical series have already appeared:

Dudebout, A. *Appareils d'essai des moteurs à vapeur; appareils d'asservissement.*
Witz, A. *Thermo-dynamique à l'usage des ingénieurs.*
Duquesnay. *Résistance des matériaux.*
Madamet, A. *Tiroirs et distributeurs de vapeur.*
Sauvage, Ed. *Les divers types de moteurs à vapeur.*
Madamet. *Détente variable de la vapeur. Dispositifs qui la produisent.*
Picou, R. V. *Dis ribution de l'électricité par usines centrales.*
Alheilig. *Recette, consérvation et travail des bois. Outils et machines-outils employés dans ce travail.*
Gouilly, Al. *Transmission de la force motrice par air comprimé ou raréfié.*
Picou, R. V. *Distribution de l'électricité par installations isolées.*
Dwelshauvers-Dery. *Étude expérimentale calorimétrique de la machine à vapeur.*
Le Chatelier, H. *Le Grisou.*
Magnier de la Source, Dr. L. *Analyse des vins.*
Schloesing fils, Th. *Notions de chimie agricole.*
Lindel, Dr. L. *La bière.*

The contributions which have already appeared are the work of distinguished specialists, and fully justify the pledge of the publishers that the promised series should be encyclopædic and thoroughly reliable. A specially valuable feature of this encyclopædia, which will doubtless add greatly to its popularity, is the fact that the volumes will be sold separately, each comprising a single subject and being complete in itself. Another useful feature of the work is the addition at the close of each volume of a list of the principal works pertaining to the subject. W.

Experiments with Alternate Currents of High Potential and High Frequency. By Nikola Tesla. New York: The W. J. Johnston Company, Limited, 167 *Times* Building. 1892.

This volume is a reprint of the classic lecture delivered by its brilliant author, before the Institution of Electrical Engineers, London, and with which electricians of both hemispheres are familiar. The publication of the lecture in book-form by making it conveniently accessible to electrical engineers and students, should insure for the work a large demand. The work is prefaced by a portrait and biographical sketch of the author.

W.

The Galvanic Circuit Investigated Mathematically. By Dr. G. S. Ohm. Translated by William Francis, with a preface by the editor, Thomas D. Lockwood, M.I.E.E. New York: D. Van Nostrand Company, 23 Murray Street. 1891. Price, 50 cents.

The volume above-named constitutes No. 102 of the well-known Van Nostrand's Science Series, and is a translation of the classic researches of the illustrious scientist who first investigated and determined the quantitative relations of the galvanic circuit and formulated the same in the law to which his name is attached. Of the host of electricians who quote and use Ohm's law in daily lecture or practice, few have probably had the opportunity of reading the original investigations by which the law was established in 1827. This is due, so far as English and American students are concerned, in part to the circumstance that the only known translation of Ohm's original work by Francis (that of Taylor's *Scientific Memoirs*) is difficultly procurable. Mr. Lockwood has rendered a service to students of the subject by placing this masterly work at their service in such convenient form. W.

Die Elektrischen Verbrauchs-Messer. Von Etienne de Foder. Wien, Pest, Leipzig. A. Hartleben's Verlag. 1891.

The present volume on electric meters forms the forty-third of the well-known and popular "Elektro-technische Biblothek" series of this publishing house.

So far as we know this is the first attempt to collect and classify in book-form the data concerning the important subiect of electric meters, and a glance through its pages will suffice to exhibit the fact that the author has displayed not only commendable zeal in his search through the literature to render his work as complete as possible, but also his thorough familiarity with the subject by his scientific arrangement and discussion of the merits of these instruments. It may be a surprise to some of our readers to know that the author describes more or less fully no less than ninety electric meters. The book is profusely illustrated and is an extremely useful addition to the literature of applied electricity. W.

Brick for Street Pavements. An account of tests made of bricks and paving blocks, with a brief discussion of street pavements and the method of constructing them. By M. D. Burke, C.E. Cincinnati: Robert Clarke & Co. 1892. 8vo. Paper. Price, 50 cents.

This work is in the form of a neatly-printed pamphlet with cover, being a reproduction of a report made by the author in his official capacity of engineer to the village of Avondale, O., on the tests made by him of various materials adapted for street paving. It embraces results of a series of tests of fifteen different varieties of clay products—bricks, paving blocks, etc. The samples submitted to examination were from as many different manufacturers, and may be regarded as representing fairly the average character of the paving bricks made in the United States.

The tests made by the author included the estimation of the following features: Chemical composition; absorption coëfficient for water; specific gravity; strength, transverse and crushing; and resistance to abrasion and impact. The author describes in full detail the methods pursued in making the tests, and presents his results in tabulated form. The report contains also an interesting discussion of the subject of street paving in general, and of the subject of the construction and maintainance of public works from the standpoint of the engineer.

The pamphlet should be useful not only to the engineer but also to the manufacturer of paving materials, containing as it does the results of a carefully conducted series of actual tests of materials in common use, and its utility is in nowise impaired by the author's intelligent comments on the general subject. W.

Ice-making Machines. The theory of the action of the various forms of cold-producing, or so-called ice machines. Translated from the French of M. Ledoux, *ingénieur des mines.* Revised and transformed to English units by J. E. Denton, D. S. Jacobus and A. Riesenberger. New York: D. Van Nostrand Company, 23 Murray Street. 1892. Price, 50 cents.

The essay of M. Ledoux, which originally appeared in the *Annales des Mines,* was translated and published in Van Nostrand's Science Series in 1879. It is a masterly discussion of the thermo-dynamic relations of the various fluids available for the production of cold, and the numerical results announced by him have been accepted by the leading manufacturers of refrigerating machinery.

Since the publication above stated, some of the constants have been re-determined experimentally, and the present translators have given the results of these newer determinations in an appendix and several new tables containing data of value to the student of the subject have been added. One feature which will make the work of Ledoux more available to American students has been introduced in the present edition, namely, the transformation of numerical values and results into English units. W.

The Railway Officials' Directory. A Guide for the Use of Railway Men and Dealers in Railway Supplies. Chicago: *Railway Age and Northwestern Railroader.* 1892.

This work, issued in pocket book form, and formerly known as *The Supply Men's Directory*, contains the addresses of Chairmen of Boards, Presidents, General Managers, General Superintendents, Purchasing Agents, Chief Engineers, Superintendents of Motive-power, Master Mechanics and Master Car-builders of all the railway companies of the United States, Canada and Mexico. The book is well indexed, making the task of reference easy. It must prove a useful publication for all whose professional and business pursuits demand an acquaintance with railway officials. The source from which it emanates should be sufficient guaranty for the accuracy of the compilation. W.

Franklin Institute.

[*Stated meeting held Wednesday, November 16, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 16, 1892.

MR. J. M. WILSON, President, in the chair.

Present, 194 members and thirty visitors.

Additions to membership since last report, seventeen.

Mr. William E. Lockwood presented a paper, entitled "The Present Status of the Question of the Hammer-blow of a Locomotive's Driving Wheels; and as supplementary to the above, the Richards Balanced Locomotive, illustrated with working model under steam."

Mr. Lockwood's communications were fully illustrated with the aid of working models and lantern slides, and called forth considerable discussion.

Mr. Emil K. Winkler, manager of the Paul Von Janko Conservatory of Music, New York, exhibited a new key-board, invented by Mr. Paul Von Janko, and described its advantages over the old form of piano key-boards.

The communication of Professor Winkler was illustrated by a piano of Decker Brothers, of New York, furnished with the Von Janko key-board; a demonstration of the capabilities of the invention was given by Miss Newcomb, of New York, who executed a number of difficult compositions upon it with great success.

At the suggestion of the President, the invention was referred to the Committee on Science and the Arts for fuller investigation and suitable recognition of its merits.

Mr. Ives exhibited a number of color photographs with the heliochromoscope in connection with the originals for comparison of the truthfulness of the rendition of color.

Mr. Robert B. Haines, Jr., presented a brief communication, descriptive of a new automatic micrometer gauge, an invention for gauging the thickness of metal plates in rolling.

On account of the lateness of the hour, the Secretary's report was dispensed with, and the meeting adjourned.

WM. H. WAHL, *Secretary.*